ASTM Bulletin

NEWS—Further Annual Meeting Notes; New Committees on Chemical Cellulose and Atmospheric Sampling and Analysis; Standards Actions.

PAPERS—Strain Effect on Polystyrene; Film Thickness Measurements; Fogging Properties of Organic Materials; Freezing Point of Antifreeze; Measuring Thermal Conductivity of Powdered Materials; Explosion Test for Load Capacity of Steel Structures; Wear Test Using Fission Fragments; Evaluation of Radiography.

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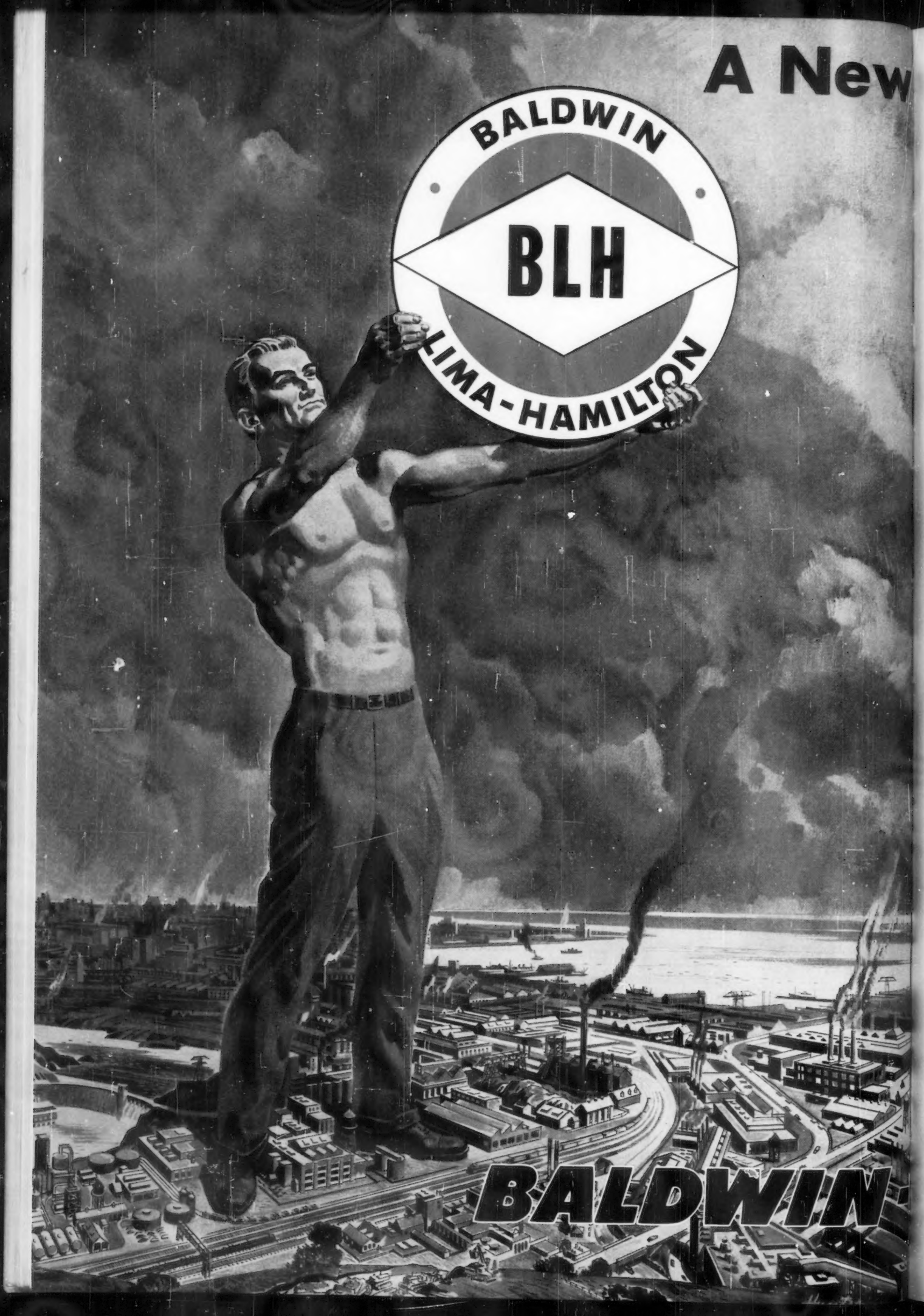
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"Promotion of Knowledge of Materials of Engineering, and Standardization of Specifications and Methods of Testing"

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Varied Technical Subjects to Feature Fifty-fourth Annual Meeting

Several Symposiums Scheduled for Atlantic City, Week of June 18

Such varied subjects as flame photometry, structural sandwiches, acoustical materials, testing of soils, surface and subsurface reconnaissance, and bulk sampling will be covered in technical symposiums at the Society's Fifty-fourth Annual Meeting to be held in Atlantic City the week beginning June 18. Some detailed information on the four first-named subjects appeared in the January BULLETIN with synopses of many of the papers. Additional information on the latter two symposiums appears below.

This Annual Meeting is about a week earlier than normal, occasioned by the necessity of getting sufficient hotel facilities and selecting a time with as few conflicts as possible with other societies. This year there will be no Exhibit of Testing Apparatus and Related Equipment nor any Photographic Exhibition, these features usually being held in the even-numbered years. These exhibits are scheduled for June, 1952, in New York City. While it is too early to give details on entertainment at the meeting, the Philadelphia District again is assuming the sponsorship of the dinner, Ladies' entertainment, and related events, and further announcement will be made.

It is known that many technical committees will convene during this week, several of them already having planned technical discussions and other features.

In addition to the several technical symposiums noted below, there will be at least the usual number of separate technical papers, and the program may be a very full one indeed. Actually the Committee on Papers and Publications has a large number of offers confronting it and just how many of these will be worked into the program will be announced later. The symposiums that are to be held (each involving one or two sessions, to be announced later) are as follows:

Flame Photometry	Consolidation Testing of Soils
Structural Sandwiches	Surface and Subsurface Reconnaissance
Acoustical Materials	Bulk Sampling

Synopses of many of the papers comprising the four first-named symposiums above appeared in the January BULLETIN, pages 16 and 17. There are given below synopses of some of the papers comprising the symposiums on Surface and Subsurface Reconnaissance and Bulk Sampling. In each symposium the papers are by leading authorities, and the intent is to provide an up-to-date picture of important developments and current thought on the respective topics.

Technical Papers:

There will be a group of technical papers concerned with various problems in the field of lead and lead products. Other individual contributions discuss laboratory tests of portland cement over a long period of time; freezing and thawing of concrete; mechanical properties of copper at various temperatures; low-temperature tension tests of metals; various papers on creep properties of certain alloys, and others. The April BULLETIN will give some further details and *the May issue, as usual, will carry the complete Provisional Program for the meeting.* This issue is a significant one, not only for the large number of members who will be attending the meeting, but also for those who are interested in subjects to be covered and who may be procuring preprints of the papers and reports.

Hotel Accommodations:

The headquarters hotel will be Chalfonte-Haddon Hall, but numerous other hotels will cooperate in providing sleeping rooms.

There will be sent to each member well in advance of the meeting complete details on room requirements. Members must keep in mind that the number of single rooms at Chalfonte and Haddon Hall is definitely limited.

Symposium on Bulk Sampling

LOUIS TANNER will discuss inexpensive collection of data in his paper "The Economic Accumulation of Variance Data in Connection with Bulk Sampling." Estimates of two variances, called "between" and "within," must be available in order to employ the techniques discussed in the paper by Tanner and Deming, "Some Problems in the Sampling of Bulk Materials," ASTM *Proceedings*, 1949. Furthermore, since bulk sampling is most often used for raw or semimanufactured control, the variances may change materially with time. Continuous redeter-

Are you interested in?: Annual Meeting Symposiums—p. 5; Marburg Lecture on Corrosion—p. 6; Actions on Standards—p. 7; Financial Highlights of ASTM—p. 10; District Activities—p. 13; Technical Committee Work—p. 15; Polystyrene—p. 29; Film Thickness Tests—p. 35; Fogging Properties—p. 40; Antifreezes—p. 43; Thermal Conductivity—p. 47; Explosion Test of Steel Structures—p. 53; Wear Test—p. 64; Radiography Evaluation—p. 66.

mination of the variances is therefore essential, but such redeterminations are costly, sometimes prohibitively so. Techniques are discussed whereby the necessary data may be accumulated during routine operations at little or no extra cost.

The development of acceptance criteria for bulk food products such as dates, figs, and nuts entering Canada is the subject of a paper by Charles W. Dunnett, of the Department of National Health and Welfare. A two-stage sampling method is described. The criteria developed give the consumer of a product reasonable protection against having poor quality lots allowed entry into Canada, and gives the importer protection, increasing with the size of the lot, against having a good quality lot refused entry.

"Sampling Characteristics of Coal" is the subject of a paper by A. A. Orning. Coal will be described from the standpoint of homogeneity in a given seam, heterogeneity of ash distribution, influence of preparation, selective size degradation, and segregation on handling. The second section of the paper will deal with analyses of variability. In this section inherent variability, trend variability, and composition of variance will be discussed. A third section of the paper will deal with sampling standards.

"Materials Handling for Bulk Sampling" will be the subject of a paper by Joseph Manuele. The paper will describe the basic requirements of a sound sampling plan particularly with regard to accuracy and economy. Also discussed will be the method of determining whether a truly representative sample has been obtained and how it is possible to be sure that the sample is representative. Various types of bulk lots are described. In continuous movement of material (coal being moved on conveyor belt) samples may be taken at periodic intervals, the sampling being timed to correspond to possible changes in the origins, or quality of, the material being moved. Therefore, for successful bulk sampling, it is necessary that we preserve the identity of individual increments in the bulk lot so that each increment may be represented in the sample, either statistically or physically. Hence, the problem of bulk sampling is a problem in material handling. If the bulk is made up of a large number of small increments, gathered from widely scattered sources, the problem becomes complicated indeed. It is necessary that information be gathered pertinent to the particular material and to the manner in which it is normally handled, and that statistical constants be calculated accordingly. Core sampling of wool, ASTM Designation D 1060–49 T is an example of this method of approach to the problem.

W. M. Bertholf's paper "The Analysis of Variance in an Incremental Sampling Experiment," will give complete formulas and appropriate computational methods for determining the three components of variance in an incremental sampling experiment, taking into account the weight of the various increments in each set. It now becomes possible to determine experimentally the "sampling constants" for a given situation with known "confidence limits." A number of examples of the use of this method in analyzing the results of previously reported experiments are given, one experiment being analyzed in considerable detail to show the method, others being reported only by summarizing the detailed computations. The use of what might be called "intermediate cross-classifications" to demonstrate "control" and adherence to the general laws of sampling, is illustrated.

Symposium on Surface and Subsurface Reconnaissance:

Abdun-Nur and Dowling will outline the engineering-geologic problems encountered by the Bureau of Reclamation in the construction of irrigation and multipurpose projects in the Plains area of the United States. The prevalence of uniform-grained fine soils and lack of granular sand and gravel and of hard durable ledge rock create problems that require the greatest ingenuity to provide for economical construction. The value of geological reconnaissance will be pointed out. The interdependency of engineering and geology will be stressed by the authors.

"Interpreting Geologic Maps for Engineers," by Eckel notes that geologic maps contain a wealth of basic information on foundations, construction materials, surface and underground water conditions, and other factors that must be considered by engineers in the planning and design of structures. Much of this information depends on interpretations of the basic data by a geologist or by the engineer. Such interpretations are an integral part of detailed geologic investigations of specific engineering sites.

A paper by Miles covers the "Application of Aerial Photographs to Preliminary Engineering Soil Surveys."

"The Practical Value of an Earth Resistivity Method in Making Subsurface Explorations" is the subject of a paper by Abercrombie which outlines explorations with the use of an electrical apparatus measuring the resistance of soils to the flow of direct current. The paper demonstrates the practical value of this apparatus in making subsurface explorations from a highway builder's point of view.

The increasing use of geophysical tests in subsurface exploration work for engineering structures is discussed by Moore, Bureau of Public Roads. After briefly covering theory and procedure in making tests in the field the author presents several practical examples in which earth resistivity tests are used in studies of subsurface problems in highway construction work.

In 1949 a project was inaugurated for the preparation of an engineering manual for District 5, Illinois Division of Highways. In order to provide accurate and up-to-date information county engineering soil maps were prepared to correlate all available information. T. H. Thornburn, University of Illinois, has a paper explaining the classification system which was adopted, the methods used in preparing the basic maps, and the technique for reproduction of the completed maps.

D. J. Belcher, Cornell University, will present an evaluation of techniques and an appraisal, by land form units, of the limitations and accuracy of airphoto reconnaissance.

F. L. LaQue to Be 1951 Marburg Lecturer

THE Board of Directors, acting on recommendation of the Marburg Lecture Committee, has extended an invitation to F. L. LaQue, in Charge of Corrosion Engineering Section, Development and Research Div., International Nickel Co., to present the 1951 Edgar Marburg Lecture at the Annual Meeting in Atlantic City during the week of June 18. Mr. LaQue, who has been very active for years in ASTM work, has accepted the invitation and members can thus look forward to a thoroughly interesting and authoritative discussion of the subject selected, which will in general relate to corrosion testing.

Mr. LaQue plans to survey the various programs and methods that have been instituted in the Society. The inadequacies of accelerated tests and the advantages and limitations of tests under natural conditions will be discussed and illustrated by appropriate data. Special attention will be given the distinction that must be made between

the corrodibility of a material and the protective value of its corrosion products and how these are influenced by both the composition of the material and the incidental conditions of its exposure.

Further details of the lecture, including an advance outline, will appear in the April ASTM BULLETIN.

Mr. LaQue is widely known for his outstanding work in the field of corrosion testing and evaluation of materials subject to this phenomenon. A graduate of Queen's University in Kingston, Ontario, he has been with the International Nickel Co. since that time, specifically in the Development and Research Division. For this entire period, his principal activities have dealt with practical aspects of corrosion and properties of metals and alloys. In addition to ASTM, he holds membership in many other professional and technical organizations.

January Actions on Standards Involving Steel, Clay Pipe, and Adhesives

MOST of the actions approved by the Administrative Committee on Standards during January cover various types of steel products, but there were two new tentatives covering Ceramic Glazed Sewer Pipe (C 261) and a recommended practice for Determining Strength Development of Adhesive Bonds (D 1144). The accompanying table lists the titles and serial designations of the new and revised standards.

Steel Products:

The new Specifications for Pipe for Low-Temperature Service (A 333) has resulted from intensive work in two cooperating subgroups in Committee A-1, Subcommittee XI on Steel Tubing and Pipe and Subcommittee XXII on Valves, Fittings, and Flanges for High-Temperature Service. Three ferritic grades are covered and reference is made that austenitic grades complying with specification A 312 have been found suitable for low-temperature service, where minimum Charpy values of 15 ft.-lb. would indicate suitability for temperatures down to 325 F. Of the ferritic grades, one is a straight carbon steel with 0.25 max. carbon and the other two are nickel alloys, the nickel ranges being about 3.5 and 5 per cent.

For the three grades, the test temperature for the notch bar impact test is −50 F. for the carbon grade and −150 F. for the two alloy grades. The minimum average impact value of these specimens ranges from 5 to 15 ft.-lb. depending on size of specimen.

In the Nut Specification (A 134) a tentative revision to be adopted later will eventually eliminate tungsten as an alternate for molybdenum in grade 3. The changes incorporated in A 193 and A 320, Bolting Materials for High- and Low-Temperature Service, and to be adopted later in A 261, clarify the requirements on a number of tests.

The Specification for Welding Fittings (A 234) embodies an important table listing the materials which are suitable for use in fabricating these fittings and consequently as new grades of specifications develop they must be considered for inclusion. The changes which will be made in A 234 are in this classification.

For some time it has been known that the Specification for Structural Steel for Ships (A 131) was somewhat out of line with latest practices and particularly with the requirements established by the American Bureau of Shipping, Lloyd's Register, and others. In this revision many of the requirements are brought in line with those promulgated by various ship interests, and the specifications will thus be more usable. The subgroup concerned is continuing its studies, and some further changes may result in a year or so. In this tentative, which applies to shapes, plates, bars, and rivets, three grades of steel are covered. The tensile strength range for the structural steel is 58,000 to 71,000 psi. and for the rivet steel and material for cold flanging 55,000 to 65,000 psi.

In the Steel Casting Specification (A 27), a basic one in this field, the silicon content will be more realistic since it is being changed from 0.60 to 0.80 per

Actions by the ASTM Administrative Committee on Standards, January, 1951

New Tentatives

Specifications for:

- Seamless and Welded Steel Pipe for Low-Temperature Service (A 333 – 50 T)
- Standard Strength Ceramic Glazed Clay Sewer Pipe (C 261 – 50 T)

Recommended Practices for:

- Determining Strength Development of Adhesive Bonds (D 1144 – 51 T)

Tentative Revisions of Standards

Specifications for:

- Carbon- and Alloy-Steel Nuts for Bolts for High-Pressure and High-Temperature Service (A 194 – 48)
- Factory-Made Wrought Carbon-Steel and Carbon-Molybdenum-Steel Welding Fittings (A 234 – 50)
- Heat-Treated Carbon-Steel Bolting Material (A 261 – 47)

Revision of Standard and Reversion to Tentative

Specifications for:

- Alloy-Steel Castings for Valves, Flanges, and Fittings for High-Temperature Service (A 157 – 50 T)
- Seamless Alloy-Steel Boiler and Superheater Tubes (A 213 – 50 T)
- Heat-Treated Steel Helical Springs (A 125 – 50 T)

Revisions of Tentatives

Specifications for:

- Alloy-Steel Bolting Materials for High-Temperature Service (A 193 – 50 T)
- Alloy-Steel Bolting Materials for Low-Temperature Service (A 320 – 50 T)
- Structural Steel for Ships (A 131 – 50 T)
- Mild- to Medium-Strength Carbon-Steel Castings for General Application (A 27 – 50 T)
- High-Strength Steel Castings for Structural Purposes (A 148 – 50 T)
- General Requirements for Delivery of Rolled Steel Plates of Flange and Firebox Qualities (A 20 – 50 T)
- Boiler and Firebox Steel for Locomotives (A 30 – 50 T)
- Open-Hearth Iron Plates of Flange Quality (A 129 – 50 T)
- Carbon-Silicon Steel Plates of Intermediate Tensile Ranges for Fusion-Welded Boilers and Other Pressure Vessels (A 201 – 50 T)
- High Tensile Strength Carbon-Silicon Steel Plates for Boilers and Other Pressure Vessels (A 212 – 50 T)
- Chromium - Manganese - Silicon (CMS) Alloy-Steel Plates for Boilers and Other Pressure Vessels (A 202 – 50 T)
- Low and Intermediate Tensile Strength Carbon-Steel Plates of Flange and Firebox Qualities (A 285 – 50 T)
- Nickel-Steel Plates for Boilers and Other Pressure Vessels (A 203 – 50 T)
- Molybdenum-Steel Plates for Boilers and Other Pressure Vessels (A 204– 50 T)
- Manganese-Vanadium Steel Plates for Boilers and Other Pressure Vessels (A 225 – 50 T)
- Chromium-Molybdenum Steel Plates for Boilers and Other Pressure Vessels (A 301 – 50 T)

cent max. The yield point of grade 120–100 in the Specifications for High Strength Casting (A 148) is to be reduced from 100,000 to 95,000 psi. The tensile strength requirements are the same.

Boiler and Pressure Vessel Plate Specifications:

The various changes in these specifications, while not extensive, will improve their utility. These standards are widely used in purchasing materials for fabrication into boilers and a wide range of other pressure vessels used in power generating, oil refining, chemical processing, and other fields. In October of last year, major changes were made in the format of the standards whereby a so-called general purpose specification giving general requirements was established, (now A 20) and much of the material that had hitherto been published in each of the product specifications was deleted therefrom and concentrated in the general-purpose document. Since then a few other matters have been noted which are covered in the current revisions. For example, in A 20 one change will permit the use of the standard $\frac{1}{2}$-in. round specimen with 2-in. gage length for testing plates down to $1\frac{1}{2}$ in. Yield point and elongation requirements were changed in A 129. Manganese requirements were increased in A 201 and A 212 to 1 per cent in order better to meet impact requirements when this material is used at low temperature.

In specifications A 203, A 204, A 302, and A 225 there is a requirement that on certain size plates if the percentage of elongation in an 8-in. specimen falls not over 3 per cent below the requirement the elongation in 2 in. across the break shall not be less than 20 per cent. This provision is set up because certain types of alloy steels show a local disproportionate increase in degree of contraction. The present thickness range, $\frac{3}{8}$ to $\frac{3}{4}$ in., is to be reduced to $\frac{1}{4}$ in. A paragraph covering this change will also be added to A 202. In several of the specifications revised tensile ranges are being embodied.

Other Specifications:

In the Alloy Pipe Specifications (A 158) tungsten is being eliminated as an alternate for molybdenum in grade P5a. This grade is the 4 to 6 per cent chromium with a molybdenum range of 0.45 to 0.65. The Bolting Specification (A 320) includes requirements on nuts and some changes will be made in these.

Several grades of material have been deleted from the Alloy Steel Casting Specifications (A 157) since they have been replaced by requirements given in Specification A 217. In the widely used Alloy Boiler and Superheater Tube Specification (A 213) a new grade of austenitic material designated, TP 310, has been added. This grade with a manganese maximum of 2 per cent has a nickel range of 19 to 22 and per cent chromium of 24 to 26.

Intensive work in Subcommittee IV on Spring Steel and Steel Springs has resulted in agreement on important revisions in the former standard for Heat-Treated Springs (A 125). This has been reverted to tentative. While a detailed description of considerations leading to this important revised tentative is perhaps unnecessary, the action of the subcommittee is an excellent example of many such projects in ASTM that result eventually in the acceptance of a useful standard. As first proposed, there were a number of objections, particularly by users, to some of the provisions and even after some compromise there was still doubt as to the changes. In Atlantic City in 1950, some of those interested brought in a rather extensive demonstration test box showing what happened when springs of various sizes were loaded. After a study of this interesting demonstration, it was not difficult for the members to reach agreement on the provisions. The springs involved are hot-coiled, compression springs which are made of bars about $\frac{1}{2}$ in. and larger and are intended primarily for use on railway equipment.

Ceramic Glazed Pipe:

The new Specification for Standard Strength Ceramic Glazed Clay Sewer Pipe (C 261) has resulted from the fact that there are several responsible companies in the United States and Canada now producing this material. It is used for conveying sewage, industrial waste, storm water, and such liquids. There are requirements on crushing strength, the resistance to action of acids, absorption tests and others.

Adhesive Bonds:

The determination of the strength of adhesive bonds is important in determining "curing" or "setting" rate of an adhesive. Hence the new recommended practice (D 1144) should be of considerable service. The practice relates to the use of all types of adherent such as metal to metal, wood to wood, glass to glass, etc.

Most of these new and revised standards will appear in the respective Supplements to the Book of Standards and thus furnished to the members, and eventually all will be available for purchase in separate pamphlet form.

NOTES ON PUBLICATIONS

Symposium on the Role of Non-Destructive Testing in the Economics of Production

THE papers presented in this Symposium, held at the 1950 Annual Meeting, are frankly aimed at capturing the attention of management and are intended to present unbiased views explaining the actual or potential values of the various well-recognized methods of non-destructive testing in promoting higher quality or more economical production.

The contributors were chosen from among men of recognized knowledge of the subject in the various fields of testing, who had extensive experience in practical applications.

Two general papers are included covering historical background, explanations of the various test methods, and generalization on the types of structural irregularities that could be detected. Three additional papers deal with specific applications of various test methods. The final one includes a general summarization, correlating the ideas expressed in the previous papers and presenting pertinent views relative to management utilization.

The papers comprising this Symposium are as follows:

A Basic Guide for Management's Choice of Non-Destructive Tests, by Robert C. McMaster and Samuel A. Wenk, Battelle Memorial Institute

Discontinuities in Cast and Wrought Products That Can Be Revealed by Non-Destructive Tests, by Kent R. Van Horn, Aluminum Company of America

The Role of Non-Destructive Testing in the Economics of Castings, by J. W. Juppenlatz, Lebanon Steel Foundry

The Economics and Practical Application of Cobalt 60 in the Radiographic Inspection of Steel Weldments, by W. Schwinn, Babcock & Wilcox Co.

The Economics of Wrought Steel Inspection, by C. D. Moriarty, General Electric Co.

Management's Responsibility for Insistence on Non-Destructive Testing in the Development of New Engineering Products and Processes, by

Leslie M. Ball, Naval Ordnance Laboratory

This symposium is another of the outstanding technical contributions sponsored by ASTM Committee E-7 on Non-Destructive Testing, formerly on Radiographic Testing. Each of the papers has been reviewed by committee members, and one can say without qualification that they are authoritative and give really up-to-date information.

Copies of the 164 page book, in heavy paper cover, can be procured at the list price of $2.50; the price to Members being $1.85. This publication has not been listed in any of the earlier Members Order Blanks. It will be available about March 1.

ASTM Standards Are Available in Separate Pamphlet Form

ONE important task involving considerable time and effort by members of the Staff is the filling of orders for copies in pamphlet form of the more than 1600 ASTM specifications and test methods. These so-called "separates" are used in a great variety of ways. Frequently, they must be attached to documents with bids and the award of contracts. Many building codes require that copies of standards referred to in the codes be kept on permanent file in city or state archieves. Separates are used in many phases of research work—there are a myriad of useful and important applications of these pamphlets.

The receipt and handling of orders for separates is an important service but it does involve much detail. Not only must each order, which may involve from one to thirty-five or more separate items, be filled carefully but the latest standards must be sent. To insure that stocks of each of these more than 1600 standards are maintained is a real task. Frequently there is delay in having the separates available because the type forms may be in use printing the Book of Standards or special compilations; but on the whole the batting average is good in supplying most separates that are needed.

One of the rooms at Headquarters which we frequently show our members and visitors is the particular stock room filled with bins from floor to ceiling in which these separates are maintained. The Book of Standards itself is an imposing volume but perhaps more impressive is to see a large room stacked with copies of the separates.

Prices of Separate Standards:

For many years we could announce that copies of separates were available at 25 cents each but with increased printing costs and handling charges some modification was necessary and the cost of each standard now depends upon the size. The following scale is in effect:

In Lots of 1 to 9:*

1 to 16 pages—25 cents each
17 to 32 pages—40 cents each
Over 32 pages—50 cents each

* Lots may consist of the same or assorted standards.

Quantity Prices:

10 to 24—10 per cent discount from above prices
25 to 100—15 per cent discount from above prices
Over 100—special quotation

There has recently been compiled a list of the standards for which 40 and 50 cent charges apply. This list follows:

40 cents (1 to 9 copies);

A 233 – 48 T.	Iron and Steel Arc-Welding Electrodes
A 316 – 48 T.	Low-Alloy Steel Arc-Welding Electrodes
C 18 – 45.	Chemical Analysis of Refractory Materials
C 169 – 43.	Chemical Analysis of Soda-Lime Glass
D 27 – 50 T.	Insulated Wire and Cable: Class AO, 30 per cent Hevea Rubber Compound
D 29 – 40 and 41 T.	Sampling and Analysis of Shellac
D 202 – 50 T.	Sampling and Testing Untreated Paper Used in Electrical Insulation
D 215 – 41.	Chemical Analysis of White Linseed Oil Paints
D 245 – 49 T.	Establishing Structural Grades of Lumber
D 271 – 48.	Laboratory Sampling and Analysis of Coal and Coke
D 276 – 49.	Identification of Fibers in Textiles
D 297 – 50 T.	Chemical Analysis of Rubber Products
D 414 – 49 T.	General Methods of Testing Cotton Fibers
D 460 – 46.	Sampling and Chemical Analysis of Soaps and Soap Products
D 500 – 45.	Chemical Analysis of Sulfonated and Sulfated Oils
D 805 – 47.	Testing Plywood, Veneer, and Other Wood and Wood-Base Materials
E 34 – 49 and 50 T.	Chemical and Photometric Analysis of Aluminum and Aluminum Base Alloys
E 35 – 49 and 50 T.	Chemical and Photometric Analysis of Magnesium and Magnesium-Base Alloys
E 37 – 50 T.*	Chemical Analysis of Pig Lead
E 46 – 50 T.*	Chemical Analysis of Lead- and Tin-Base Solder Metal
E 54 – 49 and 50 T.	Chemical Analysis of Special Brasses and Bronzes.
E 57 – 50 T.*	Chemical Analysis of White Metal Bearing Alloys
E 72 – 47 T.	Conducting Strength Tests of Panels for Building Construction
E 75 – 50 T.	Chemical Analysis of Copper-Nickel and Copper-Nickel-Zinc Alloys
E 76 – 50 T.	Chemical Analysis of Nickel-Copper Alloys

* Includes E 87 – 50 T—Photometric Analysis of Lead, Tin, Antimony and Their Alloys.

50 cents (1 to 9 copies);

A 247 – 47.	Evaluating the Microstructure of Graphite in Gray Iron
C 114 – 47 and 48 T.	Chemical Analysis of Portland Cement
D 123 – 50 and 50 T.	Definitions and Glossary of Terms Relating to Textile Materials
D 143 – 50.	Testing Small Clear Specimens of Timber
D 150 – 47 T.	Test for Power Factor and Dielectric Constant of Electrical Insulating Materials
D 296 – 49 and Use	Cotton Rubber-Lined Fire Hose for Public and Private Fire Department
D 297 – 50 T.	Chemical Analysis of Rubber Products
D 351 – 49 T.	Natural Muscovite Mica Based on Visual Quality
D 900 – 48.	Test for Calorific Value of Gaseous Fuels by the Water-Flow Calorimeter
E 3 – 46 T.	Preparation of Metallographic Specimens
E 19 – 46.	Classification of Austenite Grain Size in Steels
E 30 – 47 and 50 T.	Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron
E 31 – 47.	Chemical Analysis of Ferro-Alloys
E 45 – 46 T.	Determining the Inclusion Content of Steel
E 50 – 50 and 48 T.	Apparatus and Reagents for Chemical Analysis of Metals
E 79 – 49 T.	Estimating the Average Grain Size of Wrought Copper and Copper-Base Alloys

Additional 1950 Supplements to Standards Available

AS THIS BULLETIN nears press, additional parts of the 1950 Supplement to the Book of ASTM Standards have become available. The 1950 Supplement—Part 2—Non-Ferrous Metals, became available late in 1950; then came Part 6—Electrical Insulation, Plastics, Rubber, about February 1; and since then Part 4—Paint, Naval Stores, Wood, Adhesives, Paper, Shipping Containers.

These Supplements are sent automatically to members whose instructions concerning the Book of Standards are on file. Extra copies of the Supplements may be purchased by members at the special price of $2.75, the list price being $3.50 per part.

ASTM Bulletin

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NINETEEN-SIXTEEN
RACE STREET
PHILADELPHIA 3, PENNA.

Financial Highlights of 1950 and Some Notes on 1951 Budget

SOME interesting 1950 financial highlights are here excerpted from the report of the Executive Secretary to the Board of Directors at its meeting on January 16, 1951. A fully detailed report of the financial operations of the Society during 1950 will be included, as customary, in the next Annual Report of the Board of Directors. This will be preprinted in advance of the Annual Meeting in June.

1950 Operating Receipts:

Operating receipts for 1950 at $594,-074 were the highest in the Society's history. The accompanying table shows the major sources of receipts and gives comparable data for the two preceding years. Receipts from dues increased about the same as in recent years. Receipts from publication sales, however, were much higher, due principally to the heavy sales of the 1949 Book of Standards. Also, sales of Compilations of Standards (of which many were issued in 1950) and of separate standards contributed much to this showing. In fact receipts from sales of standards in all forms issued represent about 83 per cent of all publication sales, which demonstrates the importance of the Society's standardization work as a vital means of support of ASTM activities.

Receipts from advertising and income from investments increased materially, and the 1950 Exhibit also contributed to gross revenues.

1950 Operating Disbursements:

Operating disbursements at $523,206 are likewise an all-time high and reflect the steady growth of the Society's work. Publication costs were up substantially over the preceding year, due principally to the large number of publications issued, including the papers presented at the Pacific Area National Meeting in October, 1949, which comprise upwards of 900 pages. Increase in salaries is accounted for by increases in the Staff and salary advancements. These two items together, as in the past, account for about 80 per cent of all disbursements.

The Society's contribution to the Retirement Plan for ASTM Employees was $14,851, which was 2.8 per cent of all disbursements and about 8 per cent of the salary roll. The item of Headquarters Occupancy, plus the portion of salaries chargeable to building management, is equivalent to rent and amounts to about $2 per square foot.

It is of interest to note that the income from advertising in the ASTM BULLETIN, plus income from subscriptions to and sales of this publication, just about pay for the cost of printing the BULLETIN exclusive of overhead expenses.

Favorable Operating Balance:

It will be seen that the Society's operations in 1950 provided a favorable operating balance, which is the normal pattern for the first year of the triennial budget period represented by the years 1950-51-52. For each of the two latter years, operating receipts would normally fall below those of 1950 necessitating the use of surplus and reserve funds to balance the budgets in those two years (see statement below on 1951 Budget). The favorable operating balance permitted the building up of certain Reserve Funds to meet future requirements. Most important of these are the Reserve for General Publications and Reserve for 1952 Book of Standards, to each of which $15,000 has been added in anticipation of greatly increased costs of paper and printing that are already in effect. Other reserves to which appropriate additions have been made include two Retirement Fund Reserves and the Reserve for Depreciation of Investments. In all, $47,000 was transferred to these reserves; in addition the sum of $2500 was added to the principal of the ASTM Research Fund.

Assets and Net Surplus:

The balance sheet of the Society on December 31, 1950, showed assets in the General Funds of $439,271.50; liabilities, including accounts payable and all reserve funds, total $187,793.66, leaving a net surplus of $251,477.84, which is about 48 per cent of the current operating disbursements—in other words, enough to run the Society for about six months.[1]

In addition to the General Funds, the balance sheet also shows assets in the Building Fund of $187,152.31, which includes depreciated value of the Headquarters Building (including land) of $156,340.87; and in Committee and Other Funds of $140,057.27, these assets in each instance being balanced by liabilities of the same amounts. Thus the

OPERATING RECEIPTS

Source	1950	Per Cent	1949	Per Cent	1948	Per Cent
Dues	$205 581	34.6	$202 782	40.4	$199 892	38.6
Sales of Publications	325 998	54.8	253 127	50.4	269 952	51.5
Miscellaneous						
Advertising	32 003	...	27 470	...	19 750	...
Interest and Dividends	9 896	...	8 849	...	6 991	...
Registration Fees	7 327	...	7 135	...	6 623	...
Exhibit	8 913	...	...	...	9 665	...
Other	4 356	...	2 685	...	7 682	...
Total Miscellaneous	62 495	10.6	46 139	9.2	50 711	9.9
TOTAL RECEIPTS	$594 074	100.0	$502 048	100.0	$520 555	100.0

OPERATING DISBURSEMENTS

Item	1950	Per Cent	1949	Per Cent	1948	Per Cent
Publications	$231 825	44.2	$205 080	41.8	$196 880	42.8
Salaries	184 250	35.2	172 732	35.1	154 274	33.6
General Office Expense	42 191	8.1	42 124	8.6	40 910	8.9
Meetings and Technical and District Committees	22 311	4.3	28 291	5.8	26 890	5.8
Headquarters Occupancy	17 535	3.4	17 694	3.6	17 267	3.8
Retirement	14 851	2.8	13 699	2.8	11 251	2.5
Miscellaneous	10 243	2.0	11 251	2.3	11 955	2.6
TOTAL DISBURSEMENTS	$523 206	100.0	$490 871	100.0	$459 427	100.0

total assets of the Society are $766,481.06.

The growth of Society activities in the past decade, coupled with the influence of greatly rising costs, is reflected in the fact that in that period Society disbursements have increased 2.88 times. In the same period the net surplus has increased approximately 2.62 times.

Investments:

The book value of the Society's investments in all funds (*i.e.*, General, Building, Research, Committee, and Medal and Lecture Funds) was $311,843.07 on December 31, 1950. In view of the strong inflationary trends during the latter half of last year it was decided to increase the Society's holdings in equities in relation to holdings of fixed income securities, so that at the close of the year about 41 per cent of investments were in common stocks, 13 per cent in preferred stocks, and 46 per cent in bonds. Substantial investments were made in open-end Mutual Funds to secure diversification of investments and management service.[2]

Charts:

The charts here published give a graphic presentation of the source of the income dollar and how it was used. In the latter chart such expenses as salaries, general office expense, rent, and other overhead items have been apportioned to the three broad categories of Society work, namely, Standardization, Research, and Administration. Additions to Reserve and Surplus are also shown.

1951 Budget

In the budget for 1951, current income has been placed at $544,000, made up of dues and entrance fees of $208,000; publication sales, $285,000; miscellaneous items, $51,000. Estimated disbursements are $573,000, made up of publication costs of $237,000; salaries (including staff expansion and increases in salaries to meet current conditions), $212,000; and general office expenses, meetings and committees, headquarters, retirement and miscellaneous, $124,000. The budget for publications makes allowance for substantial increases in cost of paper and printing, which range up to 20 per cent depending on the nature of the printing; it also includes the allotment of $40,000 from current income toward the 1952 Book of Standards Reserve.

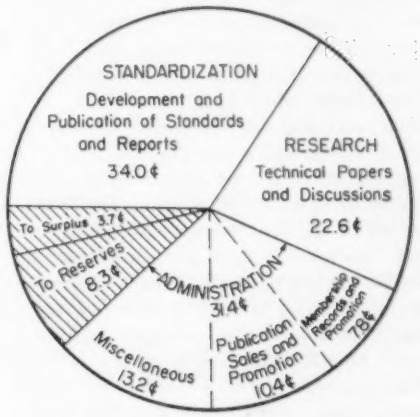
As will be seen, an operating deficit is anticipated of $29,000, which if it comes about will be met by drawing from publication and other reserve funds and from surplus. Naturally, this depends upon many factors which in these days of uncertainty and emergency can be only roughly estimated. The endeavor has been made to budget conservatively all along the line.

The Board of Directors is naturally gratified with the financial picture revealed by 1950 operations, which has made possible the strengthening of the whole financial structure of the Society in anticipation of the rough and uncertain times that may lie ahead.

[1] Since the close of the fiscal year 1950 the Board of Directors, in anticipation of the probability of having to construct an addition to the Headquarters Building and also to provide a Reserve for the greatly increased cost of replacement due to present inflation, transferred the sum of $25,000 from Surplus to a Reserve Building Account, thus decreasing the net surplus to approximately $226,500.

[2] Since the first of the year further changes were made in the investment portfolio by investing monies in Mutual Funds and certain common stocks. As a result, on January 16, 1951, the book value of all securities was approximately $334,180, of which 54 per cent was in common stocks, 14 per cent in preferred stocks, and 32 per cent in bonds.

1950 Income Dollar



How Income Dollar Was Used

Dues of Members in Armed Services Remitted

By action of the Board of Directors, the dues of personal members of the Society who enter the Armed Services of their country will be remitted for the period of their service, the membership being resumed without interruption on return to civilian life. During this period of service, regular publications will be withheld, except that the ASTM Bulletin will be mailed to such members to any designated address.

Symposium on Thermal Insulating Materials at Spring Meeting

Final plans have been virtually completed for the Symposium on Thermal Insulating Materials which is the technical feature of the Spring Meeting in Cincinnati on Wednesday, March 7. Normal procedure calls for the publication of this symposium later in the year. It is hoped to include in the April ASTM Bulletin, the next issue, a news account of the Spring Meeting, with notes on some of the highlights stressed by the authors.

TECHNICAL COMMITTEE STATEMENTS

It is planned to include in the April ASTM Bulletin, available late that month, news accounts of significant activities of technical committees resulting from meetings during ASTM Committee Week in Cincinnati throughout the week of March 5, or of meetings held by many of the committees in other industrial centers.

The purpose of this extensive article is to keep members currently up to date on many of the major developments in the technical committee work. The material is segregated according to subjects covered by the technical committees, and the reader can thus peruse the specific fields with which he is concerned.

ASTM Employees Now in Social Security

EFFECTIVE January 1, 1951, the employees of the Society come under the provisions of the Social Security Act as revised in 1950. Prior to the revision, the Society and its employees were exempt from Social Security provisions and taxes. The revised Act permits (but does not require) technical society employees to participate, provided the employer agrees to pay his share of the tax and at least two-thirds of the employees vote to participate. Last September the Board of Directors agreed to pay the employer's share of the tax, and in December more than two-thirds of the employees (41 of 54 employees) agreed to participate and pay their share of the tax.

The Board's decision to have ASTM enter Social Security was made with the understanding that Social Security benefits would be in addition to those already provided by the Society's own Retirement Plan for ASTM Employees, in which at the moment 28 employees are participating. The greatly increased retirement and other benefits of Social Security under the 1950 Act made participation for our employees attractive, and for those also in the ASTM Plan provide a worth-while addition to retirement incomes being provided under the latter plan.

Members May Get Duplicate Sales and Meeting Literature

SOME members may wonder "how come" they receive from time to time duplicate envelopes which include information about ASTM District or National Meetings, or contain literature about the Society's publications. There is considerable direct mail addressing carried on to stimulate interest in meetings of the Society including District meetings and we also distribute to various lists which are made available to the Society a considerable amount of literature describing our publications. It would be time-consuming and costly to attempt to eliminate first, all members' names and, secondly, every duplication of names, because sometimes two or more lists may be used in one project.

So, it is hoped that when members receive duplicate mailings they will understand the reasons for this. Because of the great activity of an average ASTM member, there is hardly any mailing we do to other groups that will not include quite a number of our members.

Manual for Authors of ASTM Papers

A NEW and compact Manual for Authors of ASTM Papers has recently been issued. This incorporates in convenient form such material as has been furnished to authors for many years but also includes additional data and instructions and is the Manual referred to in the article on "ASTM Papers—Their Preparation, Acceptance, and Publication" which appeared in the January, 1950, issue of the ASTM BULLETIN.

The Committee on Papers and Publications has endeavored, over the years, to keep the quality of papers published on a high plane. The principal contributing factor in this regard is the very careful scrutiny which the Papers Committee gives to all offers of papers, but more particularly the very critical review of manuscripts which the Papers Committee secures on the part of expert authorities in the field covered by the paper. However, the suggestions given to the prospective authors of papers such as those set forth in the Manual also contribute in maintaining the quality of the manuscript.

Although the new Manual and its accompanying material are primarily for the use of authors of ASTM papers, a copy of the manual will be sent on request to ASTM members who might find it of service.

Deicing a TV Antenna

ONE of the many engineering and technical problems connected with the construction of a new 200-ft. television antenna tower atop the Empire State Building was to keep the lofty structure (1450 ft. up) warm enough to prevent the formation of ice during sleet storms with consequent increase in wind loads and other hazards. To solve the problem, the Electrical Testing Laboratories of New York City determined the amount of electrical current necessary to be passed through the sections of the antenna, to prevent ice from forming.

Schedule of ASTM Meetings

DATE	GROUP	PLACE
February 26–28	Committee D-1 on Paint, Varnish, Lacquer, and Related Products	Washington, D. C.
February 27	Committee E-12 on Appearance	Washington, D. C.
March 1–2	Committee B-4 on Electrical Heating, Resistance, and Related Alloys	New York, N. Y.
March 2	Nominating Committee	Philadelphia, Pa.
March 5–9	SPRING MEETING AND COMMITTEE WEEK	Cincinnati, Ohio
March 8	Oregon Members	Portland, Ore.
March 13	Northern California District	San Francisco, Calif.
March 14–16	Committee D-13 on Textile Materials	New York, N. Y.
March 16	New York District	New York, N. Y.
March 16	Southern California District	Los Angeles, Calif.
March 19–20	Committee D-12 on Soaps and Other Detergents	New York, N. Y.
March 22	Dallas Members	Dallas, Texas
March 22	Philadelphia District	Philadelphia, Pa.
March 27	Houston Members	Houston, Texas
March 27–28	Committee D-20 on Plastics	Washington, D. C.
March 28–30	Committee D-9 on Electrical Insulating Materials	Washington, D. C.
March 29	Alabama Members	Birmingham, Ala.
March 29	Pittsburgh District	Pittsburgh, Pa.
March 29–30	Committee D-15 on Engine Antifreezes	Washington, D. C.
April 16–17	Committee D-10 on Shipping Containers	Atlantic City, N. J.
April 19–20	Committee B-1 on Wires for Electrical Conductors	Washington, D. C.
April 21	Committee C-21 on Ceramic Whiteware	Chicago, Ill.
April 23–24	Committee D-14 on Adhesives	Washington, D. C.
April 24	St. Louis District	St. Louis, Mo.
May 2–3	Committee D-21 on Wax Polishes and Related Materials	Chicago, Ill., and Racine, Wis.
May 3	Detroit District	Detroit, Mich.
May 21–22	Committee E-11 on Quality Control of Materials	Cleveland, Ohio
June 18–22	ANNUAL MEETING	Atlantic City, N. J.

Wear and Abrasion, Structural Sandwiches, Forest Research—To Be Subjects of District Meetings

Officers to Visit West Coast and Southern Centers

IN ADDITION to meetings on February 20 in Philadelphia and St. Louis, several other district and locally sponsored meetings are being arranged, a number of these in connection with visits which President Markwardt and Executive Secretary Warwick will make to West Coast and Southern industrial centers. A condensed schedule of these meetings, noting the subjects and speakers, may quickly convey what is in prospect.

Visits of Officers

Whenever possible, the President of the Society attempts to visit the two West Coast Districts centered in Los Angeles and San Francisco and usually these Districts will hold technical meetings during his visit. Added to this pattern this year is a meeting being arranged by our members in Portland, Ore., where, as is noted above, both the President and Executive Secretary will speak. Mr. Warwick, at each of the meetings on the Coast and also in the other three cities indicated, will talk on the topic "Highlights of Current ASTM Work in Materials," varying his theme in line with the principal interests of the respective localities. The officers of the two Districts in California are coordinating the plans there, and in the other cities small groups of the members have been designated as local committees on arrangements. While the personnel of these groups will be noted in a subsequent BULLETIN, heading the committees are the following: Messrs. T. K. May, Edwin Joyce, H. M. Shilstone Jr., and J. R. Trimble in Portland, Dallas, Houston, and Birmingham, respectively.

All members and friends of the Society are cordially invited to attend these meetings. Direct mail notices are going to members and committee members in each locality.

This will be the second time that there has been an ASTM sponsored get-together in the cities where no Districts are functioning. Just a year ago the Assistant Secretary, on a West Coast trip, had groups of our members together for the first time in Portland and the southern cities and the industrial importance of these areas and the increasing number of our members point up the desirability of occasional visits by officers of the Society.

DATE	PLACE	SUBJECT AND SPEAKER
Feb. 20	Franklin Inst., 20th and the Parkway, Philadelphia, Pa.	Metallurgical Development—W. A. Reich.
Feb. 20	Engineers' Club of St. Louis, 4359 Lindell Blvd., St. Louis, Mo.	Highlights of Progress in Forest Products Research—President L. J. Markwardt.
March 8	Burns Restaurant, 336 N.E. 20th, Portland, Ore.	Highlights of Progress in Forest Products Research—President L. J. Markwardt. Features of Current ASTM Work in Materials—Executive Secretary C. L. Warwick.
March 13	Engineers' Club, 206 Sansome St., San Francisco, Calif.	Timber as a Construction Material—President L. J. Markwardt. Executive Secretary.
March 16	Los Angeles, Calif.	Highlights of Progress in Forest Products Research—President L. J. Markwardt. Executive Secretary.
March 22	Franklin Inst., 20th and the Parkway, Philadelphia, Pa.	Symposium on Wear: *The Human Body* (Dinner talk), John P. Hubbard, University of Pennsylvania; *Textiles*, Charles L. Simon, Industrial By-Products & Research Co.; *Metallic Substances*, John T. Burwell, Massachusetts Institute of Technology; *Highways*, Speaker from Highway Research Board; *Lubricants & Metals (use of radioactive isotopes)*, C. F. Burk, Atlantic Refining Co.
March 22	Venus Restaurant, Dallas, Tex.	Highlights of Current ASTM Work on Materials—Executive Secretary.
March 27	Houston Club, Commerce Bldg., Houston, Tex.	Executive Secretary.
March 29	Birmingham, Ala.	Executive Secretary.

(See page 22 for notes on New York and Pittsburgh meetings)

Wear and Abrasion Testing

A significant and interesting Symposium on Wear Testing of Metals (now out of print) was sponsored in Philadelphia over ten years ago by the District; and the session at the Franklin Institute on March 22, as noted above, while on a somewhat broader theme, is in recognition of the tremendous interest in this whole subject. District Vice-Chairman E. K. Spring, Chief Metallurgist, Henry Disston and Sons, was assigned the task of procuring speakers, and the success of his efforts is indicated by the program that has been set up, each man being an authority on this particular subject. All interested are cordially invited to attend. Dinner reservations should be sent to ASTM Headquarters.

New York Meeting on Titanium

A THOROUGHLY interested audience of about 250, attending the New York District Meeting of January 12, heard two presentations on the production and the potential uses of titanium. T. W. Lippert, General Manager, Titanium Metals Corp. of America, spoke on "Derivation and Mill Fabrication," and N. E. Promisel, Head, Materials Branch and Chief Metallurgist, Bureau of Aeronautics, U. S. Navy, covered "Alloys and Their Potential Applications." Each speaker handled his subject very adequately, resulting in one of the best District meetings of the year.

This was a joint meeting with the ASME Machine Design Division, its program chairman, H. C. R. Carlson, also being the ASTM District head. He cooperated with ASTM program chairman, L. T. Work, in obtaining the speakers. Alex Stewart, Director of Research, National Lead Co., acted as technical chairman.

Although there has been as yet very limited commercial use of titanium alloys, the tonnage being quite low and the average price during 1950 aggregating in the neighborhood of $20 a pound, nevertheless some of the remarkable properties of the alloys undoubtedly justify the increased production expected during this year when possibly 150

to 200 tons of the metal may be forthcoming. Production of the metal with its high affinity for oxygen creates special smelting problems and in rolling into shapes the metal must be protected, for example by an outer layer of steel. Mr. Lippert in discussing production did not present any flamboyant picture of titanium, but gave a factual story of some of the problems, many of which are now being overcome.

Mr. Promisel, who is vitally interested in the subject from the standpoint of use in equipment for the Navy and its branches, discussed various alloys, noting that tensile strengths can be obtained in the neighborhood of 100,000 psi. with quite good yield point, but that problems include a rather low elongation and ductility. However, some of the alloys show excellent promise here. The remarkable properties of some of the alloys in resisting attack by sea water were noted.

The meeting as a whole presented an up-to-date survey of this interesting metal, and presented some factual engineering data on some of the more promising alloys.

President Markwardt at Philadelphia and Cleveland Meetings

E. J. Albert Speaks in Philadelphia on "Philadelphia and the Apparatus Industry"; N. L. Mochel in Cleveland on "Metals Currently Critical"

PRESIDENT L. J. Markwardt was the technical speaker at President's Night Meetings sponsored by the respective Districts in Philadelphia on January 16, and in Cleveland on February 5. At dinners in connection with each meeting two prominent ASTM members spoke—in Philadelphia E. J. Albert, President, *pro tem*, Scientific Apparatus Makers' Association, and President, Thwing-Albert Instrument Co., discussed "Philadelphia and the Apparatus Industry," and in Cleveland, N. L. Mochel, Manager, Metallurgical Engineering, Westinghouse Electric Corp., and Chairman of Committee A-1 on Steel, which was meeting that week, gave "Some Informal Comments on Metals Currently Critical."

Structural Sandwich Construction:

Because of the interest in composites and structural sandwich constructions, President Markwardt devoted considerable time to preparing a technical paper on this subject, and he received many compliments on this talk both in Philadelphia and Cleveland. Since there is a likelihood of the paper being published, just a sketchy outline is given here.

He referred to the derivation of the name "sandwich" which traces back to the Earl of Sandwich in England. Then he gave the following definition developed by ASTM Committee C 19 covering these materials:

"A laminar construction comprising a combination of alternating dissimilar simple or composite materials assembled and intimately fixed in relation to each other so as to use the properties of each to attain specific structural advantages for the whole assembly."

He reviewed the various types of materials such as metals, wood, and other nonmetallics which may go to make up the facings, following which notes were presented on the core materials of which there is a great variety. He discussed design criteria and in conclusion showed some interesting slides of the components, various sandwiches, and their use.

Philadelphia and the Instruments Industry:

For quite some time the Philadelphia District has wished to have a discussion on the historical and industrial aspects of Philadelphia and the instruments industry. This home city of ASTM was really the cradle of the industry, Benjamin Franklin being one of the pioneers. Mr. Albert, who devoted considerable time in preparing his material, and discussed it with such leaders in the industry as Morris E. Leeds, J. Edward Patterson, and Richard P. Brown, among others, gave many interesting historical facts. In so doing, he noted the significance of some of the organizations, in particular Queen and Co., from which stemmed a number of the leading current organizations in the instruments and supply field. Those who founded such companies as Leeds & Northrup, Arthur H. Thomas Co., J. G. Biddle & Co., and others, were at one time affiliated with Queen's.

The speaker stressed the fact that Philadelphia, the cradle of the industry, was even now the leading center for this industry. In addition to the companies noted above, and his own organization, which he very modestly did not refer to, there are other leaders in this field, including Olsen, Baldwin, Brown, RCA, Precision Thermometer, H-B Instrument Co., and others.

Mr. Albert also took the occasion to stress the key position of this industry and the necessity of maintaining it through cooperation from responsible sources in procuring material and manpower.

It is planned either to publish in full, or an extended abstract of Mr. Albert's paper.

Critical Materials:

The Cleveland District, in inviting Mr. Mochel to speak at its District Meeting Dinner on a subject to which he is very close, namely, critical metals, was conscious of the presence in Cleveland, during Committee A-1 meetings, of many leading metallurgists and engineers consuming and producing steel. His remarks, some intentionally on the light side, but mostly very serious, included among other aspects, the following: After a very trying experience in World War II, when many of those at this very meeting had serious problems and devoted much effort to conserving critical materials, we had become extremely complacent. Certainly the use of elements such as columbium and related materials had not been curtailed; very few had been conservation or very "stockpile" minded. Now, we are "paying the piper." He made reference to nickel, aluminum, and other important metals on which our peacetime and war economy depend. He noted the Society's willingness to cooperate with branches of the Government and said that a Directors' Special Committee had written to key Government men indicating the ASTM was standing ready to help where it could.

Although not minimizing the seriousness of insufficient alloys, he did not end on a pessimistic note, but stressed that we will get through somehow, although intensive effort is necessary. In all of the problems manpower is vital and he stressed the importance of this feature which is so often overlooked.

Following Mr. Mochel, President Markwardt spoke, and noted a poem, "A Nation's Greatness," which was part of his New Year's Message to our members, where, in referring to a nation's greatness, Samuel Blumenthal wrote that "the measure of a nation is the stature of its men," that "science, wealth, and power can build a super state, but the stature of its citizens alone can make it great."

Who Did It?

In Philadelphia, where Messrs. Schaefer, Albert and Spring, and Olsen, the respective District Officers, guide the District work, Henry Grinsfelder arranged the program. In Cleveland, Chairman R. T. Bayless, American Society for Metals, and Secretary L. F. Herron, The James H. Herron Co., were responsible. The Philadelphia attendance was 250, in Cleveland about 125.

ASTM TECHNICAL COMMITTEE NOTES

Steel Committee Holds 3-Day Series of Meetings

Many New and Revised Specifications to Result from Cleveland Sessions

MANY actions on steel specifications and tests took place at the mid-winter series of meetings of ASTM Committee A-1 on Steel held in Cleveland, February 5–7, inclusive. The standards related to such groups of products as steel springs, carbon and alloy bars, pipe and tubing, bolting materials, valves, flanges, and fittings for high- and low-temperature service, steel forgings, plates, structural steel, and other widely used products.

Despite the railroad strike, these meetings were among the best attended of recent years and by the use of through trains, which the railroads kept operating, and by air and car, upwards of 200 A-1 members, representing leading consumers and producers of steel, were present.

On Monday night, February 5, the ASTM Cleveland District held a technical meeting at which Norman L. Mochel, Chairman of Committee A-1 spoke at the dinner; and the Society President, L. J. Markwardt, Assistant Director, U. S. Forest Products Laboratory, Madison, gave an interesting address on "Development and Trends in Lightweight Composite Construction."

Despite the very critical shortages of alloying elements, and in fact some of the more basic materials which go to make up steel, Mr. Mochel did not take an ultra-pessimistic view. He felt that all concerned had certainly been lax in conserving and maintaining stocks of critical alloys, particularly those which are necessary for metals operating in high-temperature service; but having a backlog of experience plus a dependable technical manpower we will pull through. He stressed the importance of technical "know-how" and manpower in our materials exigency.

The District meeting was arranged by Cleveland Chairman R. T. Bayless, Assistant Secretary and Editor, American Society for Metals, and L. F. Herron, District Secretary, Secretary, and Chief Metallurgist, The James H. Herron Co.

Steel Committee Actions

More than 150 steel specifications and tests are the responsibility of Committee A-1 on Steel. Many of these standards were reviewed critically at the Cleveland meetings, and several new proposed standards were started on their way for eventual Society action at the Annual Meeting in Atlantic City in June.

It is of interest to note that one of the groups concerned with pipe and tubing, Subcommittee IX, recommended the Society issue, posthaste, emergency alternate provisions permitting a higher phosphorus in certain of the alloy steels where heavy scrap additions must be made. This should materially cut the loss of heats where it is extremely difficult to lower phosphorus to required limits without undue sacrifice of important alloys.

Steel Track Fastenings:

Changes in two standards involving track fastenings were approved subject, however, to letter ballot action and also favorable consideration by the AREA. In the Heat-Treated Carbon and Alloy Track Bolt and Nut Specification A 183, the strip test requirements are to be changed, and there is a consolidation of steel grades so that, eventually, there will be just two, a carbon steel with tensile strength of 110,000 psi. and an alloy with minimum strength of 115,000 psi. These changes will present a more realistic practice. The current standard for Quenched Carbon-Steel Joint Bars A 49 is to be reverted to tentative with some nominal changes in chemistry and a tightening of the number of test section which will require one tension and one bend test on each lot of 1000 bars, or fraction, but in no case less than one such test on each heat.

Structural Steel for Bridges and Buildings:

Among the actions affecting structural steel were changes in the Structural Nickel Steel Specification A 8 to make it applicable for use with the General Requirement Specification A 6. This material requires a tensile strength of 90,000 to 115,000 psi. minimum. Revisions in the Structural Silicon Specification A 284 will satisfy more fully the bridge engineers requirements. This specification now gives a wide range choice of mechanical properties with limitation in chemistry for various thicknesses of plate, which range from thin plates up to 12 in. in thickness.

A new Manual on Mechanical Testing Procedures for Structural Steel is being completed with action expected soon.

Spring Steel and Steel Springs:

This group completed one of the first ASTM steel specifications where hardenability requirements are the basis of purchase. The proposed tentative covers bars for springs of the 8600 (nickel-chrome-moly) series of steels. The tentative for Heat-Treated Leaf Springs, A 147–49 T, is to be advanced to standard, the former standard, carrying a '39 year date, to be dropped.

In the important field of music spring wire where Specification A 228 covers this high-quality material for springs, a revised table of tensile requirements will be adopted. This provides tensile strengths from 251,000 to 439,000 psi., the wire diameters ranging respectively from 0.156 to 0.004 in. The tensile strength for oil-tempered spring wire A 229 is to be narrowed by 5000 psi, raising all minimum values.

Forgings:

In the group of specifications covering turbine and generator parts, involving larger type forgings, higher strength steels are being added for rings and pinions for reduction gears, A 290 and A 291, and for turbine and turbine generator rotors and shafts, A 292 and A 293. A new specification for alloy steel pressure vessels was completed, but is subject to letter ballot confirmation.

This committee is drafting a Recommended Practice for the Ultrasonic Testing of Forgings, which is nearing completion. It is also drafting standardized requirements for tension testing of forgings, which should clarify this test.

Steel Tubing and Pipe:

Among the actions in Subcommittee IX was an appeal to set up emergency alternate provisions permitting higher phosphorus in certain alloy standards; the incorporation in virtually all the pipe and tube specifications of a range of check analysis for chemistry; approval of new specifications on seamless and welded tubes for low-temperature service; a new system of grade designations to apply to all of the specifications and bring better order in this respect; and the addition of new grades of low metalloid ingot iron in the specification A 253.

The producers who must use scrap which may be high in phosphorus stressed the necessity for emergency action in raising the permissible limits so that more efficient use could be made of alloy steel for products such as still tubes, boiler tubes, both seamless and welded, and austenitic seamless and welded tubing for general, sanitary, and refinery service. While ASTM has not renewed its procedures so widely used during World War II involving emergency specifications and

alternate provisions, a somewhat similar plan is expected. This involves the issuance of "pink slips" which can be affixed to the specifications, and also includes publication of the complete provisions or notice in the ASTM BULLETIN.

In the steels affected, it is proposed the present phosphorus limits of 0.030 be raised to 0.045 per cent as an emergency measure.

The new tentative for low-temperature service will cover seamless and welded carbon and alloy material. Three ferritic grades are provided, a carbon steel and two for nickel-silicon. Reference is made to austenitic grades which are suitable where Charpy impact values of 15 ft-lb. minimum are required. Rather rigorous requirements are incorporated and, in addition to chemical composition and tensile properties, the material is subject to flattening, flaring, hardness, impact, and hydrostatic tests. This new *tube* specification will be a companion standard to one recently approved for Pipe for Low-Temperature Service A 333.

On grade designations, the committee proposes to substitute for the current not-too-clear "T" numbers a new system which will use the carbon, molybdenum, chromium, or other major alloying element as the key. For example, Grade CMB would be the present low carbon-molybdenum grade; Grade CR 2¼ would be the 2¼ chromium steel and CR9 would be the nominal 9 per cent chromium alloy.

Plates for Boilers and Pressure Vessels:

The work in Committee A-1 on carbon and alloy steel plates for boilers and pressure vessels covers a heavy tonnage product, and the numerous plate specifications are widely used, many being incorporated in the Boiler Code. A grade of plate with one per cent chromium, one-half per cent molybdenum was approved. The new Manual on Mechanical Testing of Steel Plates was completed, and it likewise was started toward eventual approval in Committee A-1 and the Society. Studies will continue of additional test requirements for steel for pressure vessels at low temperatures, A 300. Check analysis requirements were approved in the Rivet Specification A 31.

It was announced at the meeting that Subcommittee XI's existing specifications had been issued in pamphlet form; this includes the new standard approved late in 1950. General Requirements for Delivery of Rolled Steel Plates, A 20, with its 13 companion product specifications covering a wide range of carbon and alloy steels. With this system for steel plates in effect, there are now two similar plans, the other on structural steel. This provides that general requirements, such as methods of conducting tests, marking, retests, and extensive tables of tolerances all of which would be common to the product specifications are in one compact document (A 20 and A 6) with the requirements on chemical composition, mechanical properties, etc., concentrated in the product standards.

Bar Steels:

ASTM has numerous specifications for carbon and alloy steel bars, some of these covering chemical requirements only, others are based on mechanical properties, some on heat treatment, while others are cold-finished material. One involves end-quench hardenability requirements, A 304, and on the latter, intensive studies have been under way to improve the requirements. A complete overhauling of this tentative, A 304, was approved in Subcommittee XV. Through the use of extensive tables and diagrams, the committee has prepared what is described as a "down-to-earth" specification which should have widespread application. Although still subject to letter ballot in the main Steel Committee, it is expected ASTM will be asked to publish the new tentative after final O.K. at the 1951 Annual Meeting.

A need for standards to govern nitriding steels has been indicated; two drafts have now been studied and after additional changes will again be distributed for comment.

Two important grades of steel are to be added to existing standards. C 1109, a carbon grade used for manufacture of nuts, is to go in the Hot Rolled Carbon Specification, A 107; and a nickel grade, A 2330, in the companion Alloy Steel Tentative, A 322.

Subcommittee XV considered the possibility of standard requirements for cold-finished carbon steel bars, but the complexities of this product, it was felt, did not indicate much promise for any agreement on a standard at this time.

Sheets:

Studies of the use of hot-rolled carbon sheets for pressure vessels resulted in agreement on a new specification for material of flange and firebox qualities. There are three grades in each classification, the carbon content ranging from 0.15 to 0.28 per cent. Tensile strength ranges are from 45,000 to 70,000 psi. with yield point minimum not less than half the tensile strength. The elongation in 8-in. gage length specimen ranges from 16½ per cent in heavier thicknesses and for the higher strength material, to 21½ per cent minimum on the thinner material in softer steel.

A new specification for commercial quality cold-rolled sheets is to be drafted.

Valves, Flanges, and Fittings for High- and Low-Temperature Service:

As usual, there was considerable activity on properties and tests of valves, flanges, and fittings for use at both elevated and for low-temperature service. Work will continue on proposed standards covering austenitic type welding fittings and also on steel castings for low-temperature service. New requirements for austenitic steel castings for service at elevated temperatures and pressures were approved. In the standard covering Forgings for Flanges and Fittings, A 182, the current one per cent chrome grade will be modified to the more popular 1¼ per cent composition. A new grade of austenitic steel, Type 304, is to be added to both the high- and low-temperature bolting specifications. In the Nut Specification, A 194, two grades of nickel-chromium steels using selenium and titanium for free machining and stabilizing will be added.

Among the recommendations affecting pipe for service at elevated temperatures were the approval of check analysis ranges in several specifications, more precise definition of "heat-treated lots," and decisions to develop new standards covering fusion-welded alloy pipe, which involves heavy wall thicknesses and sizes; and also to consider a specification for centrifugally cast steel pipe in the ferritic grades. The latter study will parallel similar work involving the austenitic grades.

The action calling for emergency increase of the permissible phosphorus limits from 0.003 to 0.045 per cent was asked in the Alloy Pipe Specifications A 158 and A 312. A study committee was set up to coordinate the various grade designations used in the family of specifications covering castings, pipe, welding fittings, forgings, and bolting.

Bolting:

For a period of two years, the wedge test, as a supplement to the tension test for determining the mechanical properties of quenched and tempered steel bolts, Specification A 325, has been under consideration. A revision has been agreed upon using the wedge under the head of the bolt as a means of assuring a properly headed bolt.

Most of the above actions are subject to letter ballot confirmation in the subcommittees and in main Committee A-1 on Steel before submission to the Society for approval.

Work on Wires for Electrical Conductors

IT IS expected that soon there will be included for the first time in any ASTM specification covering metal products, a sampling procedure based on statistical analysis and quality control. At a series of meetings held at ASA Headquarters in New York, January 16 to 18, Committee B-1 agreed to submit to letter ballot a revision of the Standard Specifications for Hard-Drawn Copper Wire (B 1–49) including these provisions. Work was authorized along similar lines on the Standard Specifications for Soft or Annealed Copper Wire (B 3–45).

In 1942 the Society published in the PROCEEDINGS a proposed specification for tinned hard-drawn and medium-hard-drawn copper wire for electrical purposes. This draft has been revised in line with present practice and is ex-

pected to be issued as a tentative specification.

Substantial agreement has been reached on the method for physical testing individual wires removed from the soft stranded cables covered by Tentative Specifications B 172, B 173, and B 174. Such tests are presently covered in the Standard Specifications for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft (B 8–50), but difficulty had been encountered in 1949 in applying similar tests in Specifications B 172, B 173, and B 174. It is now felt that revisions incorporating these changes may become effective in 1951.

The Standard Specifications for Lead-Coated and Lead-Alloy-Coated Soft Copper Wire for Electrical Purposes (B 189–50) include provisions for a lead alloy coating containing a maximum of 20 per cent tin. It has been suggested that an alloy containing 40 to 50 per cent tin would be more suitable for coating fine wire and a special group has been appointed to study this problem.

In 1949 the Society published the Tentative Specifications for Standard Weight Galvanized (Zinc-Coated) Steel Core Wire for Aluminum Conductors, Steel Reinforced (ACSR) (B 245). Experience with the specification has indicated the need of certain revisions including the requirements of the wrap test and permissible variations in diameter of the wire. Also being developed is a specification covering the more heavily coated ACSR wire.

New Standards for Copper and Copper Alloys

By all means the most significant development at the meetings of Committee B-5 on January 30 and 31 at ASTM Headquarters was the series of general requirement specifications covering wrought products. The proposed general requirement specifications under consideration are for the following classes of products:

1. Copper and copper alloy plate, sheet, and strip.
2. Copper and copper alloy rods, bars, and shapes.
3. Copper alloy wire.
4. Copper and copper alloy tubular products.

These proposed specifications were developed along somewhat the same lines as the Tentative Specifications for General Requirements for Delivery of Rolled Steel Plates, Shapes, Sheet Piling, and Bars for Structural Use (A 6–50 T) and the General Requirements for Delivery of Rolled Steel Plates of Flange and Firebox Qualities (A 20–50 T), under the jurisdiction of Committee A-1. These so-called general specifications include requirements applicable to a group of products, for example, sampling and number of tests, methods of test, retests, workmanship, inspection and dimensional tolerance tables. The general specification is referred to in the individual product specifications, and as a consequence a great volume of repetitive material is eliminated.

Committee B-5 is now engaged in revising its various wrought product quality specifications so that the material included in the general specifications will be covered only by reference.

Also being developed by subcommittees are specifications for copper alloy forgings, for automotive and refrigeration tubing, and for copper and copper alloy centrifugal castings. Because it was deemed desirable to standardize on the grades of copper-base nickel-tin-zinc casting alloys now being developed for industrial usage, it was decided to appoint a task group to draft a specification for these materials. This will be published for comment and criticism.

Use of ASTM Corrosion Test Sites

In developing the ASTM Exposure Test Site Program, a number of questions arose, one of the most important of which concerned the use of test site facilities other than by ASTM committees.

After carefully considering the advisability of permitting such use of test site facilities, the Advisory Committee on Corrosion developed a set of rules which would need to be complied with. These rules were subsequently approved by the ASTM Board of Directors at their meeting on January 16, 1951, and will appear in the 1951 Year Book as a part of the Regulations Governing Corrosion Testing.

Interest in this question has been sufficient to warrant publication prior to the issuance of the 1951 Year Book and they are being printed herewith in their entirety.

Rules Governing use of ASTM Exposure Test Sites other than by ASTM Committees

The American Society for Testing Materials established in 1941 the Advisory Committee on Corrosion, which committee is responsible for the acquisition and maintenance of ASTM exposure test sites and the review of all proposed exposure programs at these sites. This review includes tests sponsored by ASTM Technical Committees and by others who wish to use ASTM test site facilities.

1. All applications for use of ASTM test site facilities shall be made in writing to Advisory Committee on Corrosion or to the Executive Secretary of the Society. If the Advisory Committee on Corrosion approves the application, it will so advise the Executive Secretary of the Society who will inform the applicant and conclude the arrangements. Such arrangements shall include a letter form agreement setting forth (*a*) test rack location or locations, (*b*) the specific test rack structures or locations within the test sites, (*c*) the definite period of time for which permission is granted to use the ASTM facilities, and (*d*) agreement by the applicant to abide by these Rules Governing Use of Exposure Test Sites Other than by ASTM Committees.

2. The materials or products to be exposed and the purpose for which the test is made shall be within the scope of the American Society for Testing Materials. The materials or products shall be described and characterized by adequate laboratory and inspection tests approved by the Advisory Committee on Corrosion, and not identified by brand names, trade names, or similar terminology.

3. The form and size of the exposure specimens shall be acceptable to the Advisory Committee on Corrosion and in keeping with the space available at the site. The Committee shall also approve the details of specimen exposure, such as method of attachment, spacing of specimens on the test racks, location on the racks to avoid sheltering or shielding of other exposure tests, size of specimens, etc. All expenses in connection with the prepa-

ration of specimens, special supporting structures and attachment devices of any kind, transportation charges to the site, erection, etc., shall be borne by the applicant. The applicant shall submit to the Committee for approval a statement of the methods that he proposes to use in inspecting the materials or products exposed.

4. The applicant shall notify the Committee one month in advance of making any inspection and obtain approval of the time selected.

5. The Committee, at its discretion, may require the presence of a representative of the Committee when exposure, inspection, or removal of specimens is to be made. Traveling and living expenses of the Committee's representative shall be borne by the applicant.

6. The applicant shall make available to the Advisory Committee on Corrosion the results of its inspection test reports, etc., and agree to publication of such inspection data in the ASTM BULLETIN or other Society publications if so desired by the Committee. The applicant shall agree not in any way to publish, advertise, identify, or compare his materials or products exposed at the ASTM test site with any particular set of test results in ASTM publications, unless the written approval of the Executive Secretary of the Society is secured.

7. The applicant shall agree to reimburse the Society for any damages to the test racks, or to other specimens exposed on the test racks, or to enclosure fences surrounding the ASTM test site, as a result of the applicant's exposure test or visits to the test site by the applicant's personnel.

8. In case the applicant fails to abide by any of the rules outlined above, the Society reserves the right to terminate its agreement forthwith and remove from the test site any of the applicant's materials or products remaining therein.

9. If the application is granted, the Society assumes no responsibility for any damage to the applicant's specimens, nor for injury to any of the applicant's personnel engaged in erecting, inspection, or removing specimens.

Approved by ASTM Board of Directors January 16, 1951

Financial support of this broad program continues at a gratifying rate. During the month of January, contributions totaling $10,550 were received from 15 companies, making a total of $73,200 received to date. The companies contributing prior to January 1, 1951, were listed in the January BULLETIN. The 15 companies which contributed during the month of January are listed below:

Automatic Electric Co.
Bohn Aluminum & Brass Corp.
Celanese Corp. of America
Chrysler Corporation
Consolidated Gas and Electric Light and Power Co. of Baltimore
Deere & Co.
International Harvester Co.
Johns-Manville Corp.
Kaiser Aluminum & Chemical Corp.
Spencer Kellogg & Sons
Pittsburgh Steel Co.
Pratt & Lambert, Inc.
Singmaster & Breyer
Standard Oil Co. of California
Westinghouse Air Brake Co.

The next meeting of the Advisory Committee on Corrosion will be held in March and the latest developments in the establishment and equipping of the test sites will be discussed at that time. A subsequent issue of the ASTM BULLETIN will carry a summary of these developments.

Standards and Research Work on Acoustical Materials; Includes Application and Maintenance

IT IS apparent from discussions in Committee C-20 on Acoustical Materials that the need for standards in this field is very broad. Such factors as application and maintenance play an important part in the performance of acoustical materials, so that the committee has organized two active subcommittees covering these phases.

The center of activity, of course, still is the development of standards for measuring sound absorption. This subcommittee has several cooperative test programs under way, one to establish the extent of agreement of results among several reverberation chambers using three commercial materials. These materials have now been selected, two being acoustical boards and one being fiber glass. Several laboratories will cooperate in the program.

A task group is studying recent improvements in the box method apparatus which have extended its frequency range. In this method four frequencies are used for the purpose of plotting sound level values against absorption coefficients. A copy of a report covering work done to date will be distributed. A task group is working on a "close-up" method which is for use on completed installations for which the reverberation chamber is not suitable. Data are being collected on the long tube apparatus which can only be used at a frequency of 512 kc. A short tube is being developed for use with various frequencies and it is expected that it will replace the long tube apparatus. Round robin tests will be run to establish the value of the impedance tube method, the equipment for which at this time varies considerably especially in respect to the size of tube.

The Subcommittee on Fire Resistance reviewed the work of Committee E-5 on Fire Tests, especially the recent action to adopt the tunnel test method. It was the consensus that this method, being restricted as to the availability of apparatus, does not meet the needs of the committee. After considerable discussion, a task group was authorized to investigate the suitability of the panel test similar to that described in the Federal Specification SS-A-118. A group was instructed also to review the work being done on fire resistance methods in ASTM Committees C-16 and D-1.

The Subcommittee on Maintenance was informed of the relatively high cost of maintenance of acoustical ceilings in public buildings, as against plastered ceilings. The subcommittee recommended that research programs be inaugurated on paintability and the investigation of means of combating staining of acoustical materials. In this work the cooperation of the Acoustical Materials Assn. will be solicited.

Inasmuch as adhesives are the primary material involved in application of acoustical materials, the Subcommittee on Application is concerned with test methods and specifications on this material. Close liaison with Committee D-14 on Adhesives is felt necessary.

The Subcommittee on Other Physical Properties has been reviewing a number of physical properties for which standard test methods might be desirable. A task group will write and distribute a method of measuring flow resistance of perforated materials as a control test for sound absorption. A review of the present ASTM methods for measuring thermal conductivity, the guarded hot plate (C 177) and the hot box method (C 236), indicates suitability for use with acoustical materials without further adaptation. A proposed method of test for luminous reflectance of acoustical materials will be distributed for comments. This method involving the Baumgartner sphere has also been presented to Committee E-12 on Appearance for comments. A review was presented of test procedures which have been in use and which the Committee might standardize including an indentation test and methods for abrasion resistance, toughness, transverse strength,

and compressive strength. Additional significant properties for which standard methods are desirable are water resistance, linear expansion, and sag. Proposed test methods covered in this review will be prepared for circulation to the subcommittee.

The committee will hold its next meeting during the 1951 Annual Meeting of the Society in Atlantic City. It will be in conjunction with the presentation of a Symposium on Acoustical Materials sponsored by the committee. Notes on this appeared on page 17 of the January BULLETIN.

Technical Papers to Feature March Meeting of Committee D-12 on Soaps and Other Detergents

SEVERAL significant technical papers and intensive work on standard specifications and test methods are "on the docket" of Committee D-12 on Soaps and Other Detergents for its meetings on March 19 and 20 at the Hotel Park Sheraton in New York City. This ASTM Committee usually holds only one intensive series of meetings a year.

A number of technical papers by members of the committee or other leaders in this field will be presented during the two-day sessions. Some of the papers are as follows:

Laboratory Performance Test for Detergents Used in Continuous Scouring of Raw Wool, E. A. Leonard, Alexander Smith and Sons Carpet Co.

A Method of Measuring the Adsorption of Anion Active Agents on Materials Commonly Washed, W. A. Fessler, The Solvay Process Div., Allied Chemical and Dye Corp.

A Film on the Mechanical Effect Produced in Launder-Ometer Jars, O. C. Bacon, E. I. du Pont de Nemours and Co., Inc., Technical Lab.

The Use of Radioactive Tracers in the Evaluation of Metal Cleaners, H. R. Suter, Wyandotte Chemicals Corp.

Prior to the main meeting of the committee on March 20, there will be sessions of the various subcommittees.

Committee D-12 has its subcommittees arranged according to three main classifications:

(1) *Methods of Testing.*—This group is concerned with the analysis of soap, synthetic detergents, drying cleaning materials, alkaline detergents, metal cleaners, and physical testing.

(2) *Specifications.*—This group is concerned with soaps, synthetic detergents, dry cleaning, and alkaline detergents.

(3) *General or Miscellaneous Subjects.*—This includes work on nomenclature and definitions.

At the meeting in New York City, the subcommittee on physical testing will hold a round-table discussion on the various wetting evaluation methods.

Committee D-12 has issued some 35 standard specifications and test methods, and a number of proposed methods have been published to elicit criticism. In the latter category are tests for pH of Aqueous Solutions of Soaps and Detergents and for Foaming Properties of Surface-Active Agents.

New tentative specifications issued in 1950 cover Chip or Granular Soap and Solid Soap for Low-Temperature Washing, Low and Medium Titer (ASTM D 1111 and D 1112, respectively).

Detailed schedule of the meetings can be procured by writing to the Secretary of Committee D-12: H. R. Suter, Wyandotte Chemicals Corp., Wyandotte, Mich.

New Technical Committee D-22 Organized; to Cover Methods of Atmospheric Sampling and Analysis

A NEW technical committee which is to concentrate its work on the formulation of methods of atmospheric sampling and analysis, the selection of acceptable nomenclature and definitions, and the stimulation of research to accomplish the foregoing purposes, held its organization meeting at ASTM Headquarters on January 9. Dr. L. C. McCabe, Chief, Air and Stream Pollution, U. S. Bureau of Mines, who had been designated Temporary Chairman of the new committee, presided.

This committee was authorized in 1950 by the Board of Directors after discussions and conferences in which representatives of the Government, industry, and others concerned participated, with the general consensus that an ASTM technical committee could render considerable service.

A number of situations have focused attention in recent years on the seriousness of atmospheric pollution and the necessity of considering what remedial measures might be taken. Great amounts of money have been spent by industry to correct various problems. And yet underlying all of the discussions whether from the standpoint of reducing air pollution or studying local atmospheric conditions, etc., there has been a basic need for methods of sampling and analysis. Many problems are involved, but with the realization that the Society, through its time-tested procedure of bringing together various technical viewpoints on intricate problems, might aid in achieving constructive results, the Board decided to proceed. The committee will not be concerned with the fixing of permissible limits or with enforcement problems.

New Technical Committee:

Both at the organization meeting of the main committee, and at a prior meeting of a steering committee which had been appointed, problems of scope and organization were considered. Whether the work would be confined entirely to outside environments was resolved with the decision that the committee would include *both* plant and outside environments.

Originally it was felt the committee's title and its scope would include some reference to "pollution" or "air contamination," but the group concluded that any such references would narrow the scope unduly because actually much of the work may concern normal constituents and materials which are not toxic or injurious.

Subcommittee Structure:

In considering working subcommittees, there was agreement on the necessity for an Executive Group, one to consider Nomenclature and Units, and one on Instrumentation. Whether there should be separate groups on Sampling and Analytical Methods was discussed at some length, and although there was some sentiment that work involving both sampling and analytical methods should be in one group that could concentrate on particulate matter, aerosols, etc., there was finally agreement that the variety of problems could better be handled by two separate groups, and therefore the initial subcommittee organization will be as follows:

Executive
I. Nomenclature and Units
II. Methods of Sampling
III. Analytical Methods
IV. Instrumentation

Initial Projects:

Rather than devoting considerable time at the meeting to a discussion of various projects that should be considered first, the committee is to handle this by a questionnaire which will soon be distributed to the personnel. The resulting data will be analyzed and then discussed before assignments are undertaken.

Some Problems:

Some subjects which the committee is expected to consider might be noted. There is need for both integrated and instantaneous sampling procedures. Methods of analysis should be considered for aerosols and gases. Difficulties in the use of the Ringleman chart need study, particularly the checking of duplicate readings; hence, smoke density determination will be included. Clarification of terminology of measurement units will certainly be on the committee's docket.

Personnel and Officers

The initial personnel of the committee as developed by the steering committee has diversified interests represented. The following personnel was agreed on, but the membership is not necessarily closed and applications for membership will receive every consideration. The personnel, in general, however, is on a representational basis.

The election of permanent officers for the committee resulted as shown in the following list:

Chairman: L. C. McCabe, Chief, Office of Air and Stream Pollution, U. S. Bureau of Mines, Washington, D. C.

Vice-Chairman: F. S. Mallette, American Steel and Wire Co., Cleveland, Ohio

Secretary: H. H. Schrenk, Research Director, Industrial Hygiene Foundation of America, Inc., Pittsburgh, Pa.

Committee D-22 Personnel

Air Pollution and Smoke Prevention, Association of America, H. P. Munger
Aluminum Company of America, Research Laboratories, L. V. Cralley
American Air Filter Co., J. W. May
American Conference of Governmental, Industrial Hygienists, P. D. Halley
American Foundrymen's Society, F. C. Fluegge
American Gas Association, K. R. Knapp
American Industrial Hygiene Association, A. D. Brandt
American Iron and Steel Institute, F. S. Mallette
American Petroleum Institute, L. C. Burroughs
American Smelting and Refining Co., M. D. Thomas
American Society of Mechanical Engineers, M. D. Engle
American Welding Society, H. F. Reinhard
Armour Research Foundation, W. T. Savage
Association of Edison Illuminating Co., E. F. Wolf
Association of American Railroads, V. E. Amspacher
Association of American Soap and Glycerine Producers, R. L. Kramer
ASTM Committee D-19 on Industrial Water, Max Hecht
ASTM Committee E-2 on Emission Spectroscopy, B. F. Scribner
Atomic Energy Commission, W. B. Harris
Beckman Instrument Co., A. O. Beckman
Bituminous Coal Research, Inc., H. F. Hebley
Boyce Thompson Institute, P. Zimmerman
Connor Engineering Corp., W. B., Amos Turk
Dow Chemical Co., E. M. Adams
Edison Electric Institute, E. F. Wolf
General Electric Co., B. Vonnegut
General Motors Corp., D. Milne and F. A. Patty
Gray Iron Founders Society, Inc., M. F. Degley
Harvard School of Public Health, L. Silverman
Industrial Hygiene Foundation, H. H. Schrenk
Johns-Manville Research Center, D. Sinclair
Leeds and Northrup Co., G. A. Perley
Little, Arthur D., Inc., W. J. Smith
Manufacturing Chemists Association, C. A. Gosline
McCabe, L. C. (U. S. Bureau of Mines)
Mine Safety Appliance Co., W. P. Yant
National Bureau of Standards, M. Shepherd.
National Lead Co., A. V. Bender and E. J. Dunn
National Paint, Varnish and Lacquer Assn., M. W. Westgate
National Research Council of Canada, M. Katz
Ohio State University, C. E. Lapple
Radio Corporation of America, S. B. Deal
Roberts, L. M. (Research Corporation)
Schmidt, Walter (Western Precipitation Corp.)
Stanford Research Institute, P. L. Magill
Technical Association of the Pulp and Paper Industry, J. P. Casey
University of Cincinnati, Jacob Cholak
University of Illinois, H. F. Johnstone
U. S. Dept. of Army, S. D. Silver
U. S. Public Health Service, G. D. Clayton

New Committee on Chemical Cellulose

As a result of several conferences at which were present representatives not only of producers and consumers of cellulose, but also of existing ASTM technical committees and other technical organizations, the Board of Directors at its January meeting authorized the formation of a new technical committee to work in the field of cellulose and its derivatives.

Although a number of existing ASTM groups have been doing some work on cellulose in general, this has been a fringe activity, and it was felt that a committee concentrating on methods of test, recommended practices, and related standards could render distinct service to many groups.

The exact scope of the committee remains to be delineated, and further information will be given concerning this and the personnel which is in course of development.

ERRATA

ASTM Standards on Petroleum Products and Lubricants, November, 1950

On page 430 in the Tentative Specifications for Diesel Fuel Oils (D 975–50 T) the test temperature for the corrosion test specified in Section 3 (*i*) should be 122 F. and not 212 F. as printed. Section 3 (*i*) as corrected should read as follows:

> (*i*) *Corrosion.*—Tentative Method of Test for Free and Corrosive Sulfur in Petroleum Products (ASTM Designation: D 130), 3 hr. at test temperature of 122 F. The exposed copper strip shall show no gray or black deposits.

Symposium on Plasticity and Creep of Metals

We have just discovered that Figs. 7 and 8 of the paper on "Forming Parameters and Criteria for Design and Production" by William Schroeder in the Symposium on Plasticity and Creep of Metals, were interchanged in making up the symposium. The figure now appearing on page 24 is really Fig. 8 and that on page 27 is Fig. 7.

Stress Analysis

An "Introduction to Experimental Stress Analysis," by George H. Lee is a new presentation of the theory, instrumentation, and basic techniques involved in the most commonly used methods of stress analysis. In the book Mr. Lee first establishes an adequate theoretical background and then devotes the rest of his book to methods, instruments, and techniques employed.

He covers mechanical and electrical strain gages, as well as the resistance wire strain gage. A basic study of the photoelectric method is made. The brittle lacquer method, the membrane and electrical analogies, the Begg's deformeter, and certain other miscellaneous methods are also described. There is a section on the evaluation of experimental errors and the transmission of these errors through computations.

The 320-page book, with numerous illustrations, diagrams, and curves, sells for $5.50 and is published by John Wiley & Sons, Inc.

ASTM to Sponsor Session at Forest Products Research Society Meeting

In the January Bulletin announcement was made of the 1951 Annual Meeting of the Forest Products Research Society. This meeting, to be held in Philadelphia from May 7 to 11, will include an exhibit of equipment and wood products of considerable extent. An interesting feature will be a logging and sawmill show held outdoors.

The several technical sessions, covering various phases of the wood industry, are being co-sponsored with other interested societies including ASTM. The ASTM session will, as would be expected, consist of papers dealing with the testing of wood or associated materials. A tentative list of the subjects of proposed papers includes:

1. Tests and Properties of Tropical Woods.
2. The Properties of Second-Growth Redwood.
3. Fatigue Tests of Wood.
4. Methods of Evaluating Wood Preservatives.
5. The Chemical Composition of Eight Tropical Woods as Indicated by Proximate Analysis.

These papers will be under the direct sponsorship of Committee D-7 on Wood of which President Markwardt is Chairman. It would seem that a good many ASTM members will find it worth while to attend this Annual Meeting of the F.P.R.S. and its exhibits.

The themes of the other sessions appear extremely interesting and include: Logging and Primary Processing: New Machinery, Machining and Production Methods; Conversion of Woods and Mill Scrap; Mobilization of the Wood Industry; Glues and Gluing; Wood Treatment; Wood Fuel; Training Men for Wood Industries; and Wood Fabrication Problems and Joint Troubles.

President Truman Appoints Materials Commission

A late January press association dispatch from Washington indicates that President Truman has established a five-man materials policy commission to study "the broader and longer range aspects of the Nation's materials problems as distinct from immediate defense needs." ASTM members will no doubt be interested in the personnel of this group which is indicated to be as follows: William S. Paley, Chairman, Columbia Broadcasting System, will head the new group; other members are George R. Brown, Houston, Texas, business executive and engineer; Eric Hodgins, author and former *Fortune Magazine* editor; Arthur H. Bunker, Partner, Lehman Brothers, New York investment firm; and Edward S. Mason, Dean, Graduate School of Public Administration, Harvard University.

The President is quoted as saying "we cannot allow shortages of materials to jeopardize our national security nor to become a bottleneck to our economic expansion."

Brick and Tile Engineering

A new volume of engineering data on brick and tile construction has been published by the Structural Clay Products Institute, prepared by Harry C. Plummer, Director of Engineering and Technology. This volume is the revised edition of two books published earlier entitled, "Brick Engineering" and "Tile Engineering," brief reviews of which appeared in the ASTM Bulletin.

The combined edition now describes the origin, manufacture, types, and properties of structural clay products and the properties and design of brick and tile walls. Brick and tile wall sections and details, mortar, design of chimneys and fireplaces, fireproofing, and furring are discussed together with general specifications for masonry construction. Modular coordination is described in a special chapter. This volume consisting of 392 pages is available from Structural Clay Products Inst., 1520 18th St., N. W., Washington 6, D. C., at $5 per copy.

1949 Proceedings of the Highway Research Board

We have received the *Proceedings*, 29th Annual Meeting, Highway Research Board, which was held in Washington, December, 1949. This Board, organized under the auspices of the Division of Engineering and Industrial Research of the National Research Council provides a national clearing house for highway research activities and information. One important purpose is to provide a forum for the presentation and discussion of research papers and reports. This publication represents the written record of the forum as held in 1949.

The volume is divided into sections covering the several phases of highway work such as economics, finances, and administration; design; materials and construction; maintenance; traffic and operations; and soils. The headquarters of the Highway Research Board is located at the National Research Council Building, Washington 25, D. C.

Calendar of Other Society Events

"Long" and "short" calendars will appear in alternate Bulletins. *The "short" calendar notes meetings in the few immediate weeks ahead—the "long" calendar for months ahead.*

American Institute of Mining & Metallurgical Engineers—Annual Meeting, February 18–22, Jefferson Hotel, Metals Branch Session, Statler Hotel, St. Louis, Mo.

Technical Association of the Pulp and Paper Industry—Annual Meeting, February 19–22, Commodore Hotel, New York, N. Y.

American Concrete Institute—Convention, February 20–22, Hotel St. Francis, San Francisco, Calif.

Inter Society Color Council—Annual Meeting, February 28, Washington, D. C.

American Concrete Pipe Association—43rd Annual Convention, March 1–3, Waldorf-Astoria Hotel, New York, N. Y.

Canadian Society of the Plastics Industry—Annual Meeting, March 5–6, Mount Royal Hotel, Montreal, Quebec, Canada.

The Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy—Joint Meeting—Exposition of Modern Laboratory Equipment—March 5–7, Pittsburgh, Pa.

American Society for Testing Materials—Spring Meeting and Committee Week, March 5–9, Cincinnati, Ohio.

Society for Applied Spectroscopy—March 8, Socony-Vacuum Training Center, New York, N. Y.

National Association of Corrosion Engineers—Conference and Exhibition, March 13–16, Statler Hotel, New York, N. Y.

American Society of Tool Engineers—Annual Meeting, March 15–17, Hotel New Yorker, New York, N. Y.

Institute Radio Engineers—National Convention, March 19–22, Waldorf-Astoria Hotel and Grand Central Palace, New York, N. Y.

7th Western Metal Congress & Exposition—March 19–23, Oakland, Calif.

Prevention of Deterioration

The "Prevention of Deterioration Abstracts," published by the National Research Council (Prevention of Deterioration Center, Room 204), 2101 Constitution Ave., Washington 25, D. C., are offered for subscription on a yearly basis. Abstracts are classified under the headings: Biological Agents; Electrical and Electronic Equipment; Fungicides and Other Toxic Compounds; Lacquers, Paints, and Varnishes; Leather; Lubricants; Metals; Miscellaneous; Optical Instruments and Photographic Equipment; Packaging and Storage; Plastics, Resins, Rubbers, and Waxes; Textiles and Cordage; and Wood and Paper. One volume of approximately 2000 looseleaf pages is published each year in monthly issues. Subject and author indexes are compiled annually to cover abstracts issued from July through June. The yearly rate of $50 includes two sturdy binders and index tabs.

Also, an "Advance List," a monthly bibliography of all reports received in this field, is available for $10 a year.

The information contained in these abstracts should be of value especially to those concerned with military supplies to be used in arctic or tropic latitudes.

Statics and Strength of Materials, by Messrs. Draffin and Collins

Two active members of ASTM, at the University of Illinois, Messrs. Jasper O. Draffin and W. Leighton Collins, Professors of Theoretical and Applied Mechanics, have collaborated to produce this interesting textbook. It is designed specifically for students in engineering and architectural courses and embodies many references to data in ASTM publications, including standards.

Perhaps the following portion of the preface by the authors will convey a concept of the purpose of this excellent publication:

"This book is specifically designed to meet the recognized need for an elementary text covering statics and strength of materials, usable and understandable by the many students in technical and architectural courses who do not expect to pursue a rigorous engineering curriculum of four or five years, and who consequently do not carry their mathematics beyond college algebra and trigonometry. It is also suitable wherever it is found desirable to begin the study of mechanics before the calculus has been completed.

"The distinctive and somewhat unusual combination of the two subjects in one volume results directly from these needs and purposes. In statics, coplanar force systems are treated in detail by the algebraic method, and a chapter is devoted to explanation of force systems in space. The strength of materials portion covers simple structural elements involving direct stress, including welded connections, torsion, bending, and column action. While special topics of an advanced nature are not considered, the subject matter includes almost all which is commonly taught in the classroom. In a comprehensive chapter on the mechanical properties of materials and working stresses, data are presented for the more modern materials, such as light-weight alloys, high-strength steel, and plastics. The growing importance of the resistance of materials to energy, creep, repeated loading, and of stress concentrations, is recognized by a brief treatment of each of these topics."

Some 100 pages of the book in Part I are devoted to the field of statics, with 250 pages on strength of materials, in Part II. Following each chapter, there are a large number of problems which have been selected to cover broadly the fields of structures and machines, and some of these problems tie in with ASTM specifications. On this subject of specifications the authors have this to say:

Specifications.—"In order to insure that the quality of material which is in the mind of the designer is actually incorporated in the structure or machine, specifications are written which state the characteristics and properties of the material which is to be used. A specification states exactly what kind of material is to be furnished by the manufacturer or seller and the limits within which the different properties must fall. Most municipal and similar codes specify the quality of the material by referring to the specifications adopted by a standard specification writing body; probably the specifications most quoted for materials are those of the American Society for Testing Materials, usually abbreviated to ASTM."

The authors have incorporated a great amount of information through the use of extensive tables. There are a tremendous number of figures and diagrams, the total being 467; with the book itself totaling just over 400 pages one gets an idea of the wealth of illustrative material embodied.

Copies of this well-printed publication may be procured from the publishers, The Ronald Press Co., 15 E. 26th St., New York, N. Y. This book is one in a series in Engineering Mechanics edited by Glenn Murphy, another active ASTM member who is Professor of Theoretical and Applied Mechanics, Iowa State College. It is $6.50 per copy.

New York and Pittsburgh Meetings

CONFIRMATION of two interesting meetings in New York and Pittsburgh has been received. In New York, on March 16 at the Engineering Societies Building at 7:30, two technical leaders will discuss aspects of synthetic fibers. On March 29 in Pittsburgh, during the Instrument Society of America's symposium on "Instrumentation for the Iron and Steel Industry," there is a joint ASTM meeting with Wm. T. Bean, Jr., Director, Industrial Electronics, Inc., giving his dynamic lecture on "Stress Analysis in Action." All members in the New York and Pittsburgh Districts will receive direct mail notices of these respective meetings. Everyone is invited.

What's in an Automobile?

DURING a recent meeting of the Commercial Chemical Development Assn. and the Chemical Market Research Assn., C. L. McCuen, General Manager of General Motors Research Laboratory Division, in a talk on the chemical problems of the automobile industry, presented some figures showing the amount of various materials entering into the average 1950 four-door sedan some of which are shown below. (There are ASTM standards connected with every item listed.)

Pounds of Material 1950 Four-Door Sedan

Car Weight—3824.12 lb.

Steel	2556.29 lb.	Tin	1.37 lb.
Gray Iron	521.15	Fabric	92.26
Malleable Iron	99.60	Glass	76.28
Aluminum and Alloys	11.39	Lubricants	15.16
Copper	25.99	Paper	55.05
Copper Alloys	15.61	Rubber Compound	205.63
Lead and Alloys	30.39	Sound Deadener	10.83
Zinc and Alloys	66.06	Plastic, Thermosetting	2.38
Antimony	1.12	Plastic, Thermoplastic	2.87
Chromium	6.06	Tungsten	0.008
Manganese	18.82	Asbestos	2.60
Molybdenum	.08	Cork	0.626
Nickel	1.06	Mica	0.102
Silicon	17.35	Vanadium	0.0016

The Purchasing Department and Standardization

"I cannot think of a more important or useful project for a purchasing agent or anyone engaged in procurement activity generally than the subject of standardization. As a matter of fact, standards play an important part in our everyday life. . . ." There should be no question in the minds of purchasing men that the purchase of standard items is simple indeed by comparison with the acquisition of specials. We, therefore, have a lot to be thankful for because of the progress of standards through the medium of the various organizations making up the American Standards Association.

"The purchase of commodities, components, or equipment in the proper quantity—in the best available quality for the purpose—at the lowest piece price and at the time needed, form the four cardinal principles of procurement. The assistance of standards goes a long way toward assuring us that these conditions will be met. Specials, on the other hand, introduce problems of availability, higher costs, uniformity of quality, and the lack of adequate field performance data. It is difficult to have straight runs with highest efficiency in the purchase of specials. It is difficult to control inventory if you are using specials. I am sure you will agree with these comments. I am sure you realize and appreciate how much more flexibility a procurement man has when he purchases a standard item which sometimes can be shipped from stock, but in any event can be had with more reasonable assurance than the special item. Granted then that these comments are factual do we not then have an obligation to play an active part in the pursuit of further progress in standardization? Should we not actively, both as individuals and as a group, participate in the work of promoting standards? A procurement manager who does not acknowledge this obligation is lacking in assuming his responsibility in the business picture. . . ."

The above is an excerpt from a paper by V. deP. Goubeau, Vice-President in Charge of Materials, Radio Corp. of America, RCA Victor Div., Camden, N. J., entitled "The Purchasing Department's Responsibility for the Promotion of Standardization" presented at the National Standardization Conference under the Joint auspices of the National Assn. of Purchasing Agents and the American Standards Assn., New York City, November, 1950.

PERSONALS...

News items concerning the activities of our members will be welcomed for inclusion in this column.

NOTE—These "Personals" are arranged in order of alphabetical sequence of the names. Frequently two or more members may be referred to in the same note, in which case the first one named is used as a key letter. It is believed that this arrangement will facilitate reference to the news about members.

James L. Beatty, formerly Senior Testing Engineer, Pacific Islands Engineers, Guam, is now Testing Engineer, State of California, Division of Highways, Sacramento.

H. R. Beckwith has become identified with the American-Marietta Co., Kankakee, Ill., as Technical Director. He was previously Plant Manager, Reliance Varnish Co., Chicago, Ill.

William F. Black, Jr., has resigned as Editorial Assistant, American Society for Testing Materials, to become Junior Project Engineer, Sharp & Dohme, Philadelphia, Pa. Bill did some very good work for us during his relatively short stint on the Staff, but the urge to get back into industry was there. We were sorry to have him leave.

Paul Blundon is now a partner in the firm of Blundon, Snyder & Small, Consulting Engineers, Keyser, W. Va.

Robert D. Bonney, Assistant Manager of Manufacturing, Congoleum-Nairn, Inc., Kearny, N. J., was elected President of the Federation of Paint and Varnish Production Clubs at its recent 28th Annual Convention; and **Hiram P. Ball,** Assistant Secretary and Treasurer, Ball Chemical Co., Pittsburgh, Pa., was named President-elect. Messrs. Bonney and Ball have been active for many years in the work of ASTM Committee D-1 on Paint, Varnish, Lacquer, and Related Products. Mr. Bonney presently is serving as a member of the Society's Board of Directors.

Hyman Bornstein, for many years associated with Deere and Co., Moline, Ill., and for some time Manager of the Materials Engineering Dept., has been appointed Chief Technical Consultant. A note from the Company President, C. D. Wirnan, indicates that this new assignment will go far beyond the field of product development and include wide planning for future work. A member of ASTM since 1915, Mr. Bornstein has been active in the work of many committees, notably A-3 on Cast Iron, where he was secretary and later chairman for many years. The new Manager of Deere and Co. Materials Engineering Dept. is F. T. McGuire.

Jose Baraquiel Calva, of Minneapolis, Minn., internationally known chemical engineer and distinguished for his contribution to the nation's fur industry, particularly for his discovery in manufacturing plastic fur from sheep skin, has been appointed on the Public Relations Committee of the Association of Consulting Chemists and Chemical Engineers for 1951.

William Hilton Croft III, formerly Assistant Foundry Manager, Magnus Metal Div. of National Lead Co., Albany, N. Y., is now Vice-President, Hilton Supply Co., Thornwood, N. Y.

A. Davidsohn has relinquished his post as Research Chemist with the Palestine Oil Industries "Shemen" Ltd., Haifa, Israel, after fifteen years of service, to establish himself as an independent consultant in Haifa.

Henry A. Eysenbach, Jr., is now associated with the Western Electric Co., Inc., Winston-Salem, N. C., in an engineering capacity.

Elmer Gammeter, formerly Chief Metallurgist, has been appointed Director of Laboratories for the Globe Steel Tubes Co., Milwaukee, Wis.

Samuel A. Gordon, formerly Chief Structural Test Engineer, The Glenn L. Martin Co., Baltimore, Md., is now Assistant Chief of Structures, Piasecki Helicopter Corp., Morton, Pa.

Adley Walton Hemphill, following completion of graduate studies at the University of Pittsburgh, has accepted a position as Chemical Engineer, Davison Chemical Corp., Baltimore, Md.

R. Bradford Holmes has been transferred from the Parlin laboratory of the du Pont Company to the new Marshall laboratory in Philadelphia, a laboratory of the Chemical Division of the Fabrics and Finishes Department. He is supervisor of an organic group.

John C. Hostetter, active in ASTM for many years, recently President of the Mississippi Glass Co. and now Consultant, will receive the Albert Victor Bleininger Award of 1950 at a meeting at the Hotel Schenley in Pittsburgh on March 16. This high honor is conferred annually by the Pittsburgh Section, American Ceramic Society, for "distinguished achievement in the field of ceramics." Formerly with the National Bureau of Standards and the Geophysical Laboratory in Washington, D. C., Dr. Hostetter was Director of Research and Development for many years at Corning Glass Works, and subsequently was Vice-President, Hartford-Empire Co. In ASTM he was Chairman of Committee C-14 on Glass and Glass Products, and also served as Chairman of the St. Louis District.

Samuel L. Hoyt, Technical Adviser on Metallurgical Problems, Battelle Memorial Institute, Columbus, Ohio, was awarded the University of Minnesota's Outstanding Achievement Medal for his research on hard carbides and his work as adviser to Battelle. Dr. Hoyt, who founded the University of Minnesota's Department of Metallurgy, undertook research that led to development of cemented tungsten carbide, a superior tool material for cutting operations.

George T. Jones was recently appointed Asst. Metallurgical Engineer, Railroad Materials & Forgings, Carnegie-Illinois Steel Corp. (now U. S. Steel Co.), Pittsburgh, Pa. He was formerly Chief Metallurgist at the Munhall (Pa.) plant.

C. J. Knickerbocker has been named Asst. Superintendent, Production, Missouri Portland Cement Co., St. Louis, Mo. He was previously associated with the Carolina Giant Cement Co., St. George, S. C., in a similar capacity.

Paul E. Lighty, formerly Spectrographer, Limestone Products Corp. of America, Newton, N. J., is now Project Engineer, Spectroscopy, Federal Telecommunications Laboratories, Inc., Nutley, N. J.

Jess C. Little has accepted an appointment as Technical Director, Preformed Line Products Co., Cleveland. He was previously associated with the American Steel & Wire Co. of the same city in the capacity of Technical Engineer.

Herman F. Mark, Director of the Institute of Polymer Research at the Polytechnic Institute of Brooklyn, and internationally noted authority in his field, recently received an honorary degree (Doctor of Engineering) from the University of Liege, Belgium.

E. E. McSweeney, Research Supervisor, Battelle Memorial Institute, Columbus, Ohio, has assumed new responsibilities as the Institute representative to the chemical industry, in which assignment he will direct relations between Battelle and sponsors in the industry, assisting the latter in setting up their research programs. A member of the staff since 1938, Dr. McSweeney in recent years has directed plastics, rubber, and coatings research.

J. B. Monier, formerly Research Chemist, Chemical Compounds, Ltd., Galt, Ontario, Canada, is now Manager, Plastics Div., Gerry Lewis, Ltd., Toronto.

James B. Morrow, First Vice-President of the Pittsburgh Consolidation Coal Co., is recipient of the Erskine Ramsay Medal of the American Institute of Mining and Metallurgical Engineers, which medal recognizes distinguished achievement in the production, beneficiation, or utilization of bituminous or anthracite coal.

Anthony J. Nerad has been appointed Assistant Manager of the newly formed group of chemistry divisions of the General Electric Research Laboratory, Schenectady, N. Y.

E. G. Partridge, Director of Research, American Anode, Inc., Akron, Ohio, has been elected President of the Akron Council of Engineering and Scientific Societies.

Oscar Pearson, formerly Chemist and Metallurgist at Carnegie-Illinois Steel Corp. (U. S. Steel Co.), Gary, Ind., is now Division Superintendent of Steel Production at the Gary works.

Willis McGerald Peirce, Assistant to the General Manager, Technical Dept.,

New Jersey Zinc Co., Palmerton, Pa., has been elected President of American Institute of Mining & Metallurgical Engineers for 1951.

Franklin T. Peters has been appointed manager of the newly established Market Development Dept., Heyden Chemical Corp., Garfield, N. J.

The **Pittsburgh Testing Laboratory,** Pittsburgh, Pa., which has been very actively interested in the work of the Society since 1905, has announced the election of former President **A. R. Ellis** as Chairman of the Board, and Vice-President **C. M. Houck** as President. **R. C. Emmett** is now Vice-President; he was formerly Manager of the Chicago office of PTL. Representatives of the company have for many years participated actively in ASTM technical and district activities, and Mr. Ellis, a long-time member, has been concerned with the work of Committee A-1 on Steel and its subcommittees, and other groups.

Carlton H. Rose was named Manager of National Lead Co.'s Washington (D. C.) office.

John Russell, formerly Technical Director, was elected Vice-President in Charge of Production, National Glaco Chemical Co., a subsidiary of Ekco Products Co., Chicago.

Roscoe H. Sawyer, formerly Assistant Chemical Director of Devoe & Raynolds Co., Inc., Louisville, Ky., has been advanced to the post of Manager of the Technical Division of the company.

Erle I. Shobert II has been made Supervisor, Electrical Laboratories, Stackpole Carbon Co., St. Marys, Pa. He will continue also as Technical Director, Rare Metals Contacts and Non-ferrous Metallurgy.

Nicol H. Smith has been named Executive Director of the Franklin Institute's Laboratories for Research and Development, Philadelphia.

Charles E. Sohl, Jr., formerly on the faculty of the York Technical Institute, York, Pa., is now Instructor in Engineering, Pennsylvania State College, Swarthmore, Pa.

Harris M. Sullivan has been elected Vice-President and Director of Research and Development of Central Scientific Co., Chicago, Ill. Dr. Sullivan has been with the company since 1944 as Assistant Director of Research.

H. George Treibl is now Chemical Plant Operator, E. F. Drew & Co., Inc., Boonton, N. J. He was previously affiliated with Luscar Coal's Corp., Luscar, Canada, as Chemist and Assayer.

Stanton Walker, Director of Engineering, National Sand and Gravel Assn., and of the National Ready Mixed Concrete Assn., Washington, D. C., and Secretary of ASTM Committee C-9 on Concrete and Concrete Aggregates, has been elected President of the Engineers Club of Washington. Serving with him on the Board of Directors of the Club are other active ASTM members including **E. W. Bauman,** Managing Director, National Slag Assn., and **H. F. Clemmer,** Engineer of Materials, District of Columbia, Engineer Department. This club, a relatively new one in Washington, having been organized about four years ago, has its headquarters in the National Theatre Building, 1325 E St., N. W.

Paul C. Wetterau has been appointed Technical Director of Congoleum-Nairn, Inc., Kearny, N. J. He has been associated with the company for twenty years, serving entirely in the field of product development and quality control.

John M. Yahres, until recently Executive Vice-President, was elected President of Pittsburgh Screw & Bolt Corp., succeeding the late John P. Hoelzel.

Erich K. Zimmerman, formerly Director, Service Labs., Titanium Pigment Corp., New York City, is now Manager, Pigment, Paint & Chemicals, Brooklyn Laboratories, National Lead Co.

NEW MEMBERS . . .

The following 99 members were elected from December 21, 1950, to January, 26,1951, making the total membership 2679 . . . Welcome to ASTM

Note—Names are arranged alphabetically—company members first then individuals

Chicago District

BRABENDER, C. W., Consulting Engineer, Calhoun Beach Hotel, Apt. 902, Minneapolis 16, Minn.

CRABB, WARREN D., Chief Inspector, United States Steel Co., 3426 E. Eighty-ninth St., Chicago 17, Ill.

ELLIS, A. L., Secretary, The Lehon Co., 4425 S. Oakley Ave., Chicago 9, Ill.

GUTTERIDGE, R. R., Materials to Engineer, Minneapolis-Honeywell Regular Co., Aero Div., 2753 Fourth Ave., S., Minneapolis 8, Minn.

PALMER, JOHN B., Manager, Sales Engineering, Masonite Corp., 111 W. Washington St., Chicago 2, Ill.

REINECK, EDWARD A., Technical Service, The Quaker Oats Co., Merchandise Mart Plaza, Chicago 54, Ill.

SMITH, WILLIAM JONES, Architect, Childs & Smith, Architects, 20 N. Wacker Dr., Chicago 6, Ill.

WALRATH, MARTIN H., JR., Chief, Pressure Packaging and Packing Div., Quartermaster Food and Container Inst., 1849 W. Pershing Rd., Chicago, Ill. For mail: 5718 N. Winthrop Ave., Chicago 40, Ill.

Cleveland District

LAKE CITY MALLEABLE CO., THE, J. E. Micksch, Research Engineer, Box 348, Ashtabula, Ohio.

MASSILLON STEEL CASTING CO., THE, I. M. Emery, Vice-President and Works Manager, Box 388, Massillon, Ohio.

FENN COLLEGE, DEPARTMENT OF CHEMISTRY, W. E. Allsopp, Instructor of Analytical Chemistry, Cleveland 15, Ohio.

GANNETT, JOSEPH K., Vice-President and Director of Engineering and Research, The Austin Co., 16112 Euclid Ave., E., Cleveland 12, Ohio.

Detroit District

FREEMAN, FRANK H., Director of Research, Kerr Manufacturing Co., 6081 Twelfth St., Detroit 8, Mich.

MARRA, ALAN A., Research Engineer, University of Michigan, Ann Arbor, Mich.

YOHPE, R. A., Chief Engineer, Union Steam Pump Co., Battle Creek, Mich.

New England District

DEECY PRODUCTS CO., George H. Taft, Director of Research, 120 Potter St., Cambridge 42, Mass.

BARON, HOWARD M., President, Standard Mica Producing Corp., Orange, N. H. For mail: Box 31, Wappingers Falls, N. Y.

CROWELL, A. B., JR., Vice-President, Union Paste Co., 1605 Hyde Park Ave., Hyde Park 36, Mass.

MILLER, E. CRAIG, Cost and Control Dept., Bates Manufacturing Co., York Div., Saco, Me. For mail: Bay View, Saco, Me.

NICHOLS AND CO., INC., J. G. Wellman, Wool Buyer and Quality Supervisor, 140 Federal St., Boston 10, Mass.

PARKIN, GEORGE R., Chief Industrial Engineer, Arms Textile Manufacturing Co., Manchester, N. H.

VERMONT, UNIVERSITY OF, LIBRARIES, Sidney B. Smith, Director of Libraries, Burlington, Vt.

New York District

ARIZONA CHEMICAL CO., Richard Herrlinger, Research Chemist, Linden Lab., Box 152, Linden, N. J.

ENJAY CO., INC., John A. Britton, Jr., President, 15 W. Fifty-first St., New York 19, N. Y.

KELLEX CORP., THE, William B. Snow, Assistant Director of Research and Development, 233 Broadway, New York 7, N. Y.

BARTNER, BERNARD I., Chemical Engineer, Streamline Plastics Co., 171–175 Prince St., New York, N. Y. For mail: 72-19 137th St., Flushing, L. I., N. Y. [J]*

COMSTOCK, RALPH L., Plant Superintendent, Reilly Tar and Chemical Corp., 191 Doremus Ave., Newark 5, N. J.

FOURMAN, VICTOR G., President, Syntomatic Corp., 114 E. Thirty-second St., New York 16, N. Y.

GRAD, BERNARD J., Partner, Frank Grad and Sons, 187 Market St., Newark 2, N. J.

HERR, DONALD S., Director, Technical Service Lab., Shell Chemical Corp., 1120 Commerce Ave., Union, N. J.

LOPATIN, MURRAY, Junior Designer, Hydropress, Inc., 570 Lexington Ave., New York, N. Y. For mail: 490 Ocean Parkway, Brooklyn 18, N. Y. [J]

MORFIT, EDWIN F., Assistant General Superintendent, American Cyanamid Co., Plastics Dept., Bound Brook, N. J.

ROBERTS, LAWRENCE M., Manager, Development and Research Div., Research Corp., Bound Brook, N. J.

SCHEFFER, EDWARD R., Research Supervisor, Analytical Dept., National Lead Co., Titanium Div., Box 58, South Amboy, N. J.

SEDLACK, FRANK, Technical Sales Representative, United States Steel Co., Room 1418, 25 Broad St., New York, N. Y.

STERLING, CALVIN, Head, Analytical Section, International Nickel Co., Inc., Research Lab., Bayonne, N. J.

YEOMAN, DONALD CORT, Student, State University of New York, Institute of Applied Arts and Sciences, 300 Pearl St., Brooklyn, N. Y. For mail: 359 W. Twenty-second St., New York 11, N. Y. [J]

ZNAK, NICHOLAS ADAM, Junior Chemical Engineer, 111 Manhattan Ave., Brooklyn 6, N. Y. [J]

Northern California District

EITEL-MCCULLOUGH, INC., A. Arrigoni, Chief Inspector, 798 San Mateo Ave., San Bruno, Calif.

HARRIS, J. STANLEY, Testing Engineer, Perkins Gravel Co., Box 1113, Sacramento, Calif.

Ohio Valley District

CLOPAY CORP., Philip H. Rhodes, Technical Director, Clopay Square, Cincinnati 14, Ohio.

SHEFFIELD CORP., THE, William I. Wilt, Advertising and Assistant Sales Manager, 721 Springfield St., Dayton 1, Ohio.

MCINTOSH, W. R., Professor and Head, Department of Civil Engineering, University of Louisville, Louisville 8, Ky.

Philadelphia District

FRICK CO., D. Norris Benedict, President and General Manager, Waynesboro, Pa.

DYKE, W. T., Universal-Rundle Corp., 3905 River Ave., Camden 5, N. J.

GROSSEL, STANLEY, Chemical Engineer, c/o Orkin, 1830 N. Thirty-second St., Philadelphia 21, Pa. [J]

JOHNSON, LAWRENCE L., Project Engineer, Philco Corp.: Refrigeration Div., C and Tioga Sts., Philadelphia 34, Pa.

LIGGETT, ROBERT JOHN, Chemical Engineer, Tiona Petroleum Co., 501 Broad St. Station Bldg., Philadelphia 2, Pa. For mail: 900 Kerper St., Philadelphia 11, Pa.

MCKELVEY, KENNEDY MILTON, Materials Engineer, Public Works Dept., U. S. Department of the Navy, Philadelphia Naval Shipyard, Bldg. 1, Philadelphia, Pa. For mail: 51 Lewis St., E. Lansdowne, Pa.

MCLAUGHLIN, CHARLES F., Sales Manager, The Whitehall Cement Manufacturing Co., 123 S. Broad St., Philadelphia 9, Pa.

O'DELL, EARL WAYNE, Engineer, Aircraft-Marine Products, Inc., 1523 N. Fourth St., Harrisburg, Pa. For mail: 323 S. Cameron St., Harrisburg, Pa.

RANSFORD, ROBERT J., Chief Inspector, Universal Ball Co., Willow Grove, Pa.

SCHWARTZ, ANDREW, JR., Metallurgical Contact Engineer, Bethlehem Steel Co., Lebanon, Pa.

THOMAS, WILLIAM S., Manager, Foundry Div., General Machine Co., Inc., Emmaus, Pa.

Pittsburgh District

PITTSBURGH CORNING CORP., Walter Lovett, Sales Engineer, 307 Fourth Ave., Pittsburgh 22, Pa.

CHRIST, JOSEPH G., Metallurgical Engineer, Westinghouse Electric Corp., 200 McCandless Ave., Pittsburgh 1, Pa.

CROCKETT, L. O., Manager, Technical Div., Manufacturing Dept., Gulf Oil Corp., Box 1166, Pittsburgh 30, Pa.

LYDIC, ELDER RICHARD, JR., Assistant Chief Chemist, Rochester & Pittsburgh Coal Co., Indiana, Pa. For mail: 417 Oak St., Indiana, Pa.

SMITH, ROY M., Chief Engineer, Railway and Industrial Engineering Co., Box 98, Greensburg, Pa.

St. Louis District

WESTERN CARTRIDGE CO., DIVISION OF OLIN INDUSTRIES, INC., Verne Pulsifer, Metallurgical Engineer, Research Div., East Alton, Ill.

BAILIFF, N. L., Manager, Engineering Research Div., The Marley Co., Inc., 3001 Fairfax Rd., Kansas City 15, Kans.

LYTLE, C. MYRON, Manager of Engineering, Kansas City Power and Light Co., 1330 Baltimore, Kansas City, Mo. For mail: Box 679, Kansas City 10, Mo.

TROWBRIDGE, C. D., Director, St. Louis Testing Labs., 2317 Chouteau Ave., St. Louis, Mo.

Southern California District

BLY, JOHN R., Chief Inspector, General Controls Co., 801 Allen Ave., Glendale 1, Calif.

MILLER, GEORGE W., Chief Chemist, W. J. Voit Rubber Corp., 1600 E. Twenty-fifth St., Los Angeles 11, Calif.

SAYLOR, W. A., Chief Metallurgist, Consolidated Western Steel Corp., Box 2015, Terminal Annex, Los Angeles 54, Calif.

WELTY, JOHN W., Resident Chief Metallurgist, Solar Aircraft Co., 2200 Pacific Highway, San Diego 12, Calif.

Washington (D. C.) District

ADAMS, NATHANIEL M., JR., Cartographic Aide, U. S. Navy Hydrographic Office, Suitland, Md. For mail: 615 Gresham Pl., N. W., Washington 1, D. C.

DEFORE, MARTIN R., Materials Engineer, National Bureau of Standards, Washington 25, D. C.

EVANS, DONALD N., Materials Engineer, National Bureau of Standards, Washington, D. C. For mail: 5320 Glenwood Rd., Bethesda 14, Md.

FRENCH EMBASSY, INDUSTRIAL ANALYSIS BRANCH, R. Donn, Chief, 1704 Eighteenth St., N. W., Washington 9, D. C.

GENEVEY, LOUIS PAUL, Assistant to French Air Attaché, French Embassy, 1759 R St., N. W., Washington 9, D. C.

HAUPT, C. G., Chemist, Norfolk & Western Railway Co., Chemical Lab., Roanoke 17, Va.

MCCABE, LOUIS C., Chief, Office of Air and Stream Pollution, Bureau of Mines, Department of the Interior, Washington 25, D. C.

MCKINLEY, JAMES M., Chief, Physical Test Lab., Aberdeen Proving Ground, Bldg. 525, Aberdeen Proving Ground, Md. For mail: 217 W. Lorraine Ave., Baltimore 11, Md.

NEWMAN, E. S., Chemist, National Bureau of Standards, Washington 25, D. C. For mail: 4604 Addison Rd., N. E., Washington 19, D. C.

Western New York—Ontario District

GUSTAFSON, JACK H., Chief Chemist, Marlin-Rockwell Corp., 402 Chandler St., Jamestown, N. Y.

HAAG, WAYNE B., Chief Metallurgist, Marlin-Rockwell Corp., 402 Chandler St., Jamestown, N. Y.

SKINNER, CLAYTON H., Technical Superintendent, Hewitt Rubber Div., Hewitt-Robins, Inc., 240 Kensington Ave., Buffalo 5, N. Y.

U. S. and Possessions

ANDERSON, CLAYTON AND CO., Earl E. Berkley, Director, Fiber Lab., Box 2538, Houston 1, Tex.

LUFKIN FOUNDRY AND MACHINE CO., J. B. Hopper, Chief Engineer, Lufkin, Tex.

TENNESSEE PRODUCTS AND CHEMICAL CORP., L. A. Miller, Vice-President, Research Dept., 4800 Central Ave., Chattanooga, Tenn.

LOOMIS, R. J., Laboratory Supervisor, Socony-Vacuum Oil Co., Inc., Box 240, Casper, Wyo.

MANILA FIRE DEPT., Cipriano Cruz, Chief, Manila, Philippines.

MILLER, ROBERT P., JR., Vice-President, Southwestern Graphite Co., Burnet, Tex.

MURPHY, MALCOM, JR., Partner, Murphy Boiler and Piping Co., Petroleum Bldg., Shawnee, Okla. [J]

WINBLADE, FRANK N., Chief, Seattle Lab., National Bureau of Standards, University of Washington Campus, Seattle 5, Wash.

Other than U. S. Possessions

OULUJOKI OSAKEYHTIO, Jukka E. Vuorinen, Civil Engineer, Leppiniemi OL., Finland.

AGGEBRINK, GUNNAR, General Manager, Plast AB HAGA, Anderstorp, Sweden.

ARMSTRONG, E. K., City Engineer, Dunedin City Council, Municipal Chambers, Octagon, Dunedin C 1, New Zealand.

BADCOCK, FRED, Works Manager, Kango Electric Hammers, Ltd., Morden Factory Estate, Lombard Rd., South Wimbledon, London S. W. 19, England. For mail: 5 Dulwich Village, London S. E. 21, England.

BERNDTSSON, BERNDT, Chemical Engineer, Svenska Oljeslageri AB, Goteborg 5, Sweden.

FOSTER, R. G., Production Manager, The Winnipeg Supply and Fuel Co., Ltd., Eighth floor, Boyd Bldg., Winnipeg, Man., Canada. For mail. 21 Lipton St., Winnipeg, Man., Canada.

KHAN, MUKHLESOZZAMAN, Assistant Director, Central Testing Lab., Government of Pakistan, Karachi, Pakistan. For mail: 1825 R St., N. W., Washington, D. C.

LAORDEN, JOSE, Instituto Tecnico de la Construccion y del Cemento, Velazquez 47, Madrid, Spain. For mail: 1108 W. Stoughton, Urbana, Ill.

LATIF, JAMES I., Executive Engineer, Punjab Government, Public Works Dept., Irrigation Branch, Khanwah Div., Canal Colony, Montgomery, Punjab, Pakistan.

NICHOLLS, G. F., Technical Controller, Holeproof, Ltd., 204 Sydney Rd., Brunswick, Melbourne, Australia.

PAVOT, E., Inspecting Engineer, "The Continental Inspection," 31 Rue Jean Jaures, Marcinelle, Charleroi, Belgium.

VAN OUWERKERK, LAMBERTUS, Management Director, Rontgen Technische Dienst, 21F Oost Siedelinge Rotterdam/Overschie, The Netherlands.

* [J] denotes Junior Member.

To the ASTM Committee on Membership, 1916 Race St., Philadelphia 5, Pa.

Gentlemen:

Please send information on membership to the company or individual indicated below:

_____

_____

This company (or individual) is interested in the following subjects: (indicate field of activity, that is, petroleum, steel, non-ferrous, etc.,)

_____

Signed _____

Date_____ Address_____

NECROLOGY . . .

The Death of the following members has been reported

A. G. Anderson, Automotive Standards Engineer, International Harvester Co., Chicago, Ill. (October 10, 1950). Member since 1943.

K. J. Broadbooks, Tennessee Eastman Co., Div. of Eastman Kodak Co., Kingsport, Tenn. Representative of his company since 1947 on Committee D-13 on Textile Materials and many of its subgroups.

P. D. Gaskill, Vice-President and Treasurer, The Whitehall Cement Manufacturing Co., Philadelphia, Pa. (November 29, 1950). Member since 1925.

Edward M. Hughes, Chief Chemist, Refinery, Sun Oil Co., Marcus Hook, Pa. (February 2, 1951). A member of ASTM since 1920, Mr. Hughes had been with the Sun Oil Co. for 39 years. He was also a member of the Franklin Institute and the American Chemical Society.

Charles E. Joos, Manager, Water Purification Div., Cochrane Corp., Philadelphia, Pa. (January 7, 1951). Member since 1936, and member of Committee D-19 on Industrial Water and several of its subcommittees for the same period.

R. H. Rawson, Consulting Timber Engineer, Portland, Ore. (November 20, 1950). Member since 1949, and consulting member of Committee D-7 on Wood since 1948.

H. A. Roth, Chief Chemist, Rundle Manufacturing Co., Camden, N. J. (May 25, 1950). Member since 1943.

Spencer Gray Scoular, City Engineer, Dunedin City Council, Dunedin, New Zealand (October 22, 1950). Member since 1939.

Harry W. Stark, Civil Engineer, United Fruit Co., Boston, Mass. Member since 1930.

J. N. Wickert, Assistant Superintendent, Carbide and Carbon Chemicals Division, Union Carbide and Carbon Corp., South Charleston, W. Va. (January 24, 1951). Representative of company membership since 1943. Also represented his company since 1943 on Committees B-3 on Corrosion of Non-Ferrous Metals and Alloys and D-16 on Industrial Aromatic Hydrocarbons; and served as a member of Committee D-2 on Petroleum Products and Lubricants and several of its subgroups since 1946, and of Committee D-3 on Gaseous Fuels since 1947.

Melville C. Wylie, for many years President, and more recently Chairman of the Board of Directors, Gulick-Henderson Laboratories, Inc., Pittsburgh, Pa., Residence, Edgewood, Pa. (January 27, 1951). Representative of company membership since 1938, and a member of ASTM Pittsburgh District Council since 1942. A leader in the field of health service, Mr. Wylie in his earlier years had been chief clerk of the Allegheny Bureau of Health and also had been with the Pittsburgh Health Bureau in a similar capacity. He had been associated with the Gulick-Henderson Laboratories since 1916.

E. H. Zeitfuchs, Manager, Standard Instrument Co., Berkeley, Calif. (November 3, 1950). Member since 1947.

The Society Appoints . . .

Announcement is made of the following appointments of Society representatives

W. H. Rowand, Babcock and Wilcox Co., on the Joint Committee on Effect of Temperature on the Properties of Metals.

B. W. Scribner, National Bureau of Standards, on Joint ASTM-TAPPI Committee on Paper Testing Methods, to succeed R. C. Griffin, Arthur D. Little, Inc., resigned.

R. W. Crum, National Research Council, reappointed on American Documentation Institute.

P. G. McVetty, Westinghouse Electric Corp., on the Charles B. Dudley Medal Committee, to replace E. E. Thum, American Society for Metals, resigned.

H. H. Lester, Watertown Arsenal, on ASA Sectional Committee Z54 on Safety Code for the Industrial Use of X-rays.

E. O. Hausmann, Continental Diamond Fibre Co., on ASA Sectional Committee C55 on Capacitors.

R. W. White, Ordnance Department, on ASA Sectional Committee on Electrical Insulating Materials, succeeding W. R. Fuller, Pratt & Lambert, Inc.

J. M. Hardesty, Bell Telephone Laboratories, Inc., on ASA Sectional Committee A42 on Plastering, succeeding L. S. Wells, National Bureau of Standards.

J. H. Foote, Commonwealth Services, Inc., as third representative on ASA Standards Council.

J. R. Townsend, Bell Telephone Laboratories, Inc., reappointed as Society representative on ASA Mechanical Standards Committee.

Report on Professional Development

The Eighteenth Annual Report of the Engineers' Council for Professional Development (ECPD), which is a conference of engineering bodies, has become available. Copies of this 56-page document (8½ by 11 in.) can be procured by writing the Council at 29 W. 39th St., New York 18, N. Y.; a nominal charge of 50 cents is made.

Essentially, this Council, which is supported by eight constituent engineering organizations, has the objectives of improving the methods by which a man becomes an engineer, increasing the usefulness of his engineering studies, and clarifying the procedures by which he becomes recognized professionally. Probably its best known work is the examining and accrediting of engineering curricula. Over 600 of these have been approved in 142 engineering schools. Details are given in the Annual Report

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To the ASTM Committee on Membership

1916 Race St., Philadelphia 3, Pa.

Gentlemen:

Please send me information on membership in ASTM and include a membership application blank

Signed _____

Address _____

Date _____

LABORATORY SUPPLIES . . .

Catalogs and Literature and Notes on New or Improved Apparatus

Note—This information is based on literature and statements from apparatus manufacturers and laboratory supply houses.

Catalogs and Literature

Universal Testing Machines—A new 30-page catalog on Riehle Screw Power Universal Testing Machines and accessories is now being offered by the manufacturer. The catalog includes illustrations, details of construction, specifications, and dimensions of testing machines up through 400,000 lb. capacity. Information is also given on special tools, instruments, and accessories for special tests. Copies of the catalog may be obtained without charge from any Riehle representative or by writing Riehle Testing Machines Division.

Riehle Testing Machines Div., American Machine and Metals, Inc., East Moline, Ill.

Contour Projector—What the Kodak Contour Projector Model 2 is—and how it can be used to magnify dimensions, shapes, and surfaces in production or tool making— is the subject of a new descriptive booklet now being offered by the Eastman Kodak Co. Some of the special jobs that the projector can do as a matter of routine include, as shown in the booklet, looking into deep recesses, exploring and measuring sizable concavities in one continuous operation at high magnification, and checking intricate dimensional relationships. The projector also simplifies the staging of parts. Specifications, optics, and accessories for the Kodak Contour Projector Model 2 are described in considerable detail. The booklet has eight pages, liberal illustrations, and is 8½ by 11 in. in size.

Industrial Optical Sales Division, Eastman Kodak Co., Rochester 4, N. Y.

Manual of Laboratory Safety—The Fisher Scientific Co. announces the publication of a newly revised edition of the 40-page booklet entitled "Manual of Laboratory Safety." The original material has been brought up-to-date by the inclusion of recently developed data, techniques, and equipment; the new manual will prove to be useful in the implementation of complete laboratory safety programs. The original edition of this manual has been translated into many foreign languages and is widely used in laboratories throughout the world.

Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Pa.

Camera Microscope—A Universal Camera Microscope for Metallurgical Work, originating in Austria, is claimed to be the most compact and easiest to operate equipment of its kind. It has a built-in camera and a magnification of from 4.5 to 2200 times. Stated as outstanding features of this instrument are the instant changeover from bright to dark ground illumination, the instantaneous transition from visual observation to photography and from ordinary to polarized light. Methods of illumination include Vertical (bright-ground), Oblique Internal (bright-ground), Flat Oblique Multilateral (dark-ground), and Unilateral External (dark-ground). Convenient for micrography. Le Chatelier principle. Drawing and projection micro hardness tester accessories.

William J. Hacker & Co., Inc., 82 Beaver St., New York 5, N. Y.

Method for Determining Solids in Boiler Water—A method described as simple and quick for determining the solids content of boiler water or condensate is outlined and illustrated in Bulletin 2RE50, just issued by Hall Laboratories, Inc. The test procedure for boiler water utilizes a Hagan Conductivity Meter in conjunction with a cell, a Hagan Dial Thermometer, a conductivity cylinder, and a supply of Conductivity Reagent A. Samples may be tested at any convenient temperature as the Meter has a temperature compensator. In testing condensate, Conductivity Reagent A is not required. A half dropperful of the reagent is sufficient to neutralize a boiler water sample and an excess is not harmful. With the thermometer remaining in the sample, the cell, electrically connected to the meter, is placed in a sample and the compensator set at the temperature indicated. A directional "eye" on the meter—in a circuit developed by Hall Laboratories—permits almost instant determination of the proper dial setting. The dial reading in micromhos (a unit of electrical conductivity) may be used directly or translated into parts per million of solids by use of a suitable factor.

Hall Laboratories, Inc., Hagan Bldg., Pittsburgh 30, Pa.

Recorder for Spectrographic Analyses—A new brochure describes the use of the Brown "Electronik" strip chart recorder in connection with the Bausch and Lomb Densitometer. This combination according to the brochure affords speed, accuracy, and reproducibility of results. A graph included in the brochure indicates that lines which would not be readily apparent by visual examination are made clear and precise by the recorded curve.

Instrumentation Data Sheet No. 10.16-12, Minneapolis-Honeywell Regulator Co., Industrial Div., Philadelphia 44, Pa.

Force-Balance Controller—The development of a force-balance, nonindicating controller—the "Transet Tri-Act Controller"—for pneumatic transmission systems has been announced by the Taylor Instrument Companies. The new Controller, incorporating a new control circuit, is said to give: (1) faster, more accurate measurement of rapidly changing temperatures and pressures; (2) closer process control with stability; (3) continuous process records on a 30-day strip chart, together with all other features needed for efficient remote control—all in a 4⅜ by 5-in. miniature pneumatic receiver.

Bulletin 98097, Taylor Instrument Companies, Rochester 1, N. Y.

Instrument Notes

High-Speed Inkless Strain Recorder—A new recording SR-4 strain amplifier which reproduces both static and rapidly changing SR-4 strain gage measurements of strains, forces, fluid pressures, displacements, vibrations, acceleration, etc., on a strip chart with rectangular coordinates, is announced by the Testing Equipment Department of the Baldwin-Lima-Hamilton Corp. It is known as the Baldwin-Sanborn recorder. The instrument is a direct-writing, inkless vacuum-tube voltmeter consisting of (1) an a-c. powered strain gage amplifier; (2) a D'Arsonval moving coil recording galvanometer; (3) a paper drive mechanism. Features include extreme ruggedness and simplicity of operation. The writing arm has a heated stylus which wipes across heat-sensitive record paper as it is pulled over a sharp, straight edge by the paper drive mechanism, thus producing a black line on a white background. The instrument is available in a mahogany case 17 by $11\frac{23}{32}$ by $9\frac{7}{16}$ in. overall, weighing 32½ lb., or may be obtained without case in two sections for panel mounting. In addition to use with strain gages, the instrument can be used with temperature-sensitive elements such as the Baldwin Type T-14 and can reproduce any electrical phenomena ranging from a few millivolts to more than 200 volts.

Baldwin-Lima-Hamilton Corp., Paschall Station, Philadelphia 42, Pa.

Press for Preparation of Metallurgical Specimens—Metallurgical laboratory operators will be interested in the new No. 1330 AB speed press announced by Buehler, Ltd. This new streamlined press with a 10,000 lb. capacity is designed to provide the metallurgist with a new tool for the speedy and practical preparation of mounted specimens in either opaque bakelite or crystal clear plastic compounds. Molds, heating, and cooling blocks are interchangeable for the various size requirements: 1, 1¼, and 1½ in. mountings. The hinged press head is supplied with a semiautomatic lock and a hand wheel screw to lock the mold securely. Heating blocks are arranged with a magnetic closure to snugly envelop the mold assembly. The interchange of thermostatically controlled heating units of 600 watt capacity is facilitated by convenient supports. The cooling blocks are located in a practical position in front of the AB speed press cabinet. Literature giving complete information on this new piece of metallurgical equipment available on request.

Buehler Ltd., 165 W. Wacker Drive, Chicago 1, Ill.

Permeability Meter—The latest developments in permeability testing are said to be embodied in the new Dietert No. 335 "Permmeter." The construction complies with all of the requirements for standard A.F.S. stopwatch permeabilities and also provides for automatic permeabilities, independent of operator attention. The familiar orifice method has been added for rapid control testing. A clear plastic permeability scale marks a definite improvement in accuracy for this method.

Harry W. Dietert Co., 9330 Roselawn Ave., Detroit 4, Mich.

Laboratory Tongs—For those who work around laboratory furnaces, a product has been developed for unusually safe

handling of sample crucibles. With the New Fisher Jumbo Crucible Tongs, operator's hand need not be exposed to extreme furnace heat. The Jumbo Tongs are nearly 21 in. long, and are made of 18/8 stainless steel. Control of crucibles is improved by a patented handle which provides separate grips for the thumb and one finger. The hand firmly supports the entire weight of the crucible and tongs, because the handle extends well beyond the finger grips. To prevent the handles from slipping out of alignment, joints of the new tongs are flattened.

Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Pa.

Thickness Gage—A new thickness gage, developed by Maynard R. Euverard of the Interchemical Corp., is designed for use in high precision measurements of the dry thickness of nonelectrical conductive coatings and other sheet-like materials. The product may be used on aluminum and other non-ferrous metals. A brochure available from the Henry A. Gardner Laboratory, Inc., lists construction features of the product.

Henry A. Gardner, Laboratory, Inc., 4723 Elm St., Bethesda, Md.

Calculator—A new desk calculating instrument for statisticians in industrial quality control, engineering research, and the human sciences is available. This instrument, the Merrill RMS Slide-Disk, simplifies the computation of standard deviations, root-mean-squares, correlation coefficients, regression lines, etc. By graphic calculation, statistical results are said to be obtained in a fraction of the time previously required and to an accuracy of ½ per cent or better. Time savings result from the fact that as many as five mathematical steps are performed in one mechanical operation taking about two seconds to complete. The RMS Slide-Disk consists of a 10-in. disk that slides and rotates under a pair of vertical and horizontal scales on which a series of right triangles are formed graphically. RMS Slide-Disks are furnished with linear and logarithmic scales and an instruction manual. All critical parts are made of dimensionally stable Vinylite plastic.

Graphic Calculator Co., 633 Plymouth Court, Chicago 5, Ill.

Armored Conductivity Cells for Sulfuric Acid—Armored conductivity cells for the measurement of strong sulfuric acid concentrations are announced by Industrial Instruments, Inc., manufacturers of electrolytic conductivity control equipment. The new cells are supplied in pairs with one cell as the reference and the other as the measuring cell. The pressure seal has been redesigned to completely eliminate dependence upon glass parts. Designed for pipe line installations, the cells are suitable for line pressures up to 50 psi. The cells are made of heavy wall Pyrex with platinum electrodes and matched cell constants of 1.00. Metal parts are of either steel or type 316 stainless steel.

Industrial Instruments, Inc., 17 Pollock Ave., Jersey City 5, N. J.

New Recorder for Test Data—A new electronic recorder announced by Leeds & Northrup Co. features a range continuously adjustable over a 20:1 ratio, and zero suppression adjustable over more than twice the maximum range. Through use of a particular suppressed zero range, an operator can ignore that portion of the range in which he is not interested, while he spreads the few millivolts he wants to watch across the entire width of the instrument chart. Some typical measurements include: (1) measurements with strain gages; (2) temperature difference measurements with thermocouples; (3) speed measurements. Calibrated d-c. millivoltage range is adjustable from a minimum across-chart span of 1.1 mv. to a maximum range span of 22 mv. Uncalibrated coarse and fine rheostats provide maximum zero suppression of —50 or +50 mv., continuously adjustable between these limits.

Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia 44, Pa.

Silent Blast Burner—The Precision-Martin Silent Blast Burner is designed for glass working and other heating jobs requiring a wide range of flame sizes, shapes, and temperatures. Offering extremely flexible, convenient operation, the Precision-Martin Burner has the feature of noiseless burning. The valves controlling air, oxygen, and gas are located conveniently for simplified flame control. Gas flow is controlled by a centrally mounted cock which swings through an arc of 90 deg. The pilot burner mounted on a telescoping shaft facilitates lighting and maintaining the master flame. The burner comes equipped with three interchangeable nozzles, 7, 19, 31 ports, which modify the intensity of the flame. Overall dimensions 9 in. high, 9 in. long, and 5 in. wide. Weight approximately 7 lb.

Precision Scientific Co., 3737 W. Cortland St., Chicago 47, Ill.

INSTRUMENT COMPANY NEWS . . . .

Announcements, changes in personnel, new plants and locations, and other notes of interest

Bausch & Lomb Optical Co., 635 St. Paul St., Rochester 2, N. Y. Appointment of Dr. Robert J. Meltzer to Bausch & Lomb Optical Co.'s Scientific Bureau is announced by Carl L. Bausch, Vice-President in charge of Research and Engineering. A physicist, Dr. Meltzer graduated from Rensselaer Polytechnic Institute, Troy, N. Y., and earned his doctorate at Johns Hopkins University, Baltimore, last year.

Alfred Bicknell Associates, 243 Broadway at Windsor St., Cambridge, Mass. Dr. Frederick G. Keyes, Chairman of the Department of Chemistry of Massachusetts Institute of Technology for 23 years, has been named vice-president and director of Alfred Bicknell Associates, Inc. Announcement of the appointment was made today by Mr. Alfred Bicknell, chairman of the Board. Dr. Keyes assumed his new duties January 1.

Corning Glass Works, Corning, N. Y. Amory Houghton, Chairman of the Board of Corning Glass Works announced today that the Company will commemorate its hundredth anniversary in 1951. The Glass Works was founded in Somerville, Mass., in 1851, as the Union Glass Company by Amory Houghton, great-grandfather of the present Chairman. The enterprise moved to Brooklyn in 1864 and, four years later, was transferred to Corning by canal boat. Today, not including its subsidiaries and affiliated companies, Corning Glass Works employs over 8000 residents in the Corning area and over 4000 in other cities including Central Falls, Rhode Island; Wellsboro, Pa.; Bradford, Pa.; Charleroi, Pa.; Muskogee, Okla.; Albion, Mich.; Parkersburg, W. Va.; and Leaside, Ontario, Canada.

Weston Electrical Instrument, Newark, N. J., has announced the appointment of Thomas H. Closs as sales representative of Weston for northeastern and eastern Maryland. Mr. Closs will maintain his offices in metropolitan Baltimore at 17 W. Pennsylvania Ave., Towson 4, Md.

Handbook for Concrete and Cement

A good example of the recognition and use of ASTM standards in other than our own publications is the Handbook for Concrete and Cement recently published under the auspices of the Corps of Engineers, U. S. Army Waterways Experiment Station, Vicksburg, Miss. This handbook is a compilation of specifications and standardized methods of testing and has been prepared for use in both the laboratory and field. This edition, dated August, 1949, supersedes the edition published in October, 1942.

The handbook is issued in two editions; a complete edition, priced at $4 per copy designed primarily for use by laboratory personnel, and an abridged edition which contains those items believed to be of greatest interest and usefulness to field personnel. It is issued in loose-leaf form, thus facilitating the addition of supplementary and revisions of existing items.

It is interesting to note that out of approximately 135 methods of tests and specifications covering concrete, aggregate, cement, curing, water, and miscellaneous items, about 60 are actual ASTM standards adopted in complete form. A good many of the remaining items are alternate methods or deal with subjects not covered by the interested ASTM technical committees.

Personnel at the Waterways Experiment Station responsible for this compilation under the supervision of Herbert K. Cook include Bryant Mather, assisted by T. B. Kennedy, E. J. Callin, R. L. Curry, Katherine Mather, C. H. Willets, and J. C. Woolsley, several of whom are prominent and active members of ASTM Committees C-1 on Cement and C-9 on Concrete and Concrete Aggregates.

Effect of Strain Rate on the Tensile and Compressive Stress-Strain Properties of Polystyrene

By C. C. Hsiao[1] and J. A. Sauer[1]

SYNOPSIS

The effect of rate of straining on both the tensile and compressive stress-strain properties of polystyrene has been studied. A simple, inexpensive apparatus has been devised for maintaining a constant rate of strain throughout duration of the test and for permitting various constant rates of strain to be applied. The apparatus has been used to run tests at rates of strain ranging from 5×10^{-6} per sec. to approximately 700×10^{-6} per sec.

Under tensile loading, polystyrene at room temperature is observed to behave in a brittle manner over the entire strain range investigated. The fracture strain, for example, varied very little, if at all, with changes of strain rate, and all of the tensile fractures occurred at an elongation of 1.4 to 1.5 per cent. Under compressive loading, the observed behavior was more like that of a ductile material. There was a considerable amount of plastic flow at all investigated rates of straining, and fracture, as such, did not occur even though the tests were continued until a 16 per cent strain change had occurred.

Modulus of elasticity and maximum stress are both found to increase with increase of testing speed whether the applied load be tensile or compressive. For a four-fold strain rate increase, the increase in modulus is approximately 4.5 to 5 per cent for tensile loading and approximately 2 per cent for compressive loading. The maximum tensile stress and the maximum compressive stress are found to vary linearly with the log of the strain rate.

For a given material, mechanical properties such as modulus of elasticity, yield stress, and tensile strength are generally recognized to be a function of the type of stress applied to the specimen, of the temperature of the material, and of the rate of load (or strain) application. Although this last variable, rate of strain, is frequently of negligible importance for certain properties of some materials, such as for the room-temperature modulus of elasticity of steel, in many other instances changes in rate of strain produce significant variations in stress-strain characteristics. This is particularly true of high polymers where the changes caused by variations in rate of loading even at room temperature conditions are sufficiently large to require consideration.

Although this general topic has recently received some attention in the literature (1, 2, 3),[2] a great deal of test information is needed before the behavior of plastic materials under variable rates of strain can be accurately predicted. One of the reasons, perhaps, why more information is not available is the inability of most existing testing apparatus to maintain a constant strain rate throughout the duration of test and to be sufficiently flexible to permit the desired wide range of strain rates—representative of practice—to be applied. One of the objectives of the present study was, therefore, to construct simple and inexpensive apparatus that would provide a strain rate range of at least 100 to 1 and at the same time would maintain the strain rate essentially constant throughout the duration of the test.

In order to provide maximum correlation of test results, it was decided to use a material for which considerable information on both the elastic and anelastic properties had already been accumulated. Lustrex, a commercial grade of polystyrene was, therefore, a natural choice as its stress-strain behavior under normal rates of loading, its creep behavior under long-time loads, and its damping behavior under rapidly alternating loads had previously been studied and reported (4, 5, 6, 7, 8).

It was decided also to run stress-strain tests under compressive loads as well as tensile loads so that some information would be available on the effect of variable rates of straining on compressive stress-strain properties. Compression tests are somewhat more difficult to carry out, and the results are subject to further difficulties of interpretation because of such things as the variation of the state of stress and the state of strain due to bulging, end friction, and localized deformation. Nevertheless, because of the need for information on the behavior of plastics under compressive loading, tests were made and are reported herein along with the results of the tension tests.

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to ASTM Headquarters, 1916 Race St., Philadelphia 3, Pa.

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[2] The boldface numbers in parentheses refer to the list of references appended to this paper.

TEST SPECIMENS

The tension specimens were cut from molded polystyrene sheets $\frac{19}{32}$ in. in thickness and were machined to an over-all size of $8\frac{1}{2}$ by 1 in. The center section of the specimen was reduced to $\frac{5}{8}$ in. over a 2-in. gage length and the reduced section joined to the 1-in. section by a 3 in. radius. All specimens were hand polished with fine sandpaper in the longitudinal direction.

A number of preliminary tests were run on specimens of different sizes to determine the most suitable type of compression specimen. As a result of these tests, a cylindrically shaped specimen $\frac{9}{16}$ in. in diameter and 1 in. in length was selected. All specimens were cut from the molded polystyrene sheets and tested with the axis of the specimen parallel to the original molded surfaces of the sheets.

All specimens were stored in the constant temperature (77 ± 2 F.), constant humidity (50 ± 2 per cent R.H.) chamber for at least 72 hr. prior to tests, and all tests were conducted on a modified Dillon testing apparatus which was kept in the same room.

APPARATUS AND CONTROL SYSTEM FOR CONSTANT STRAIN RATE TESTS

Both the tension and compression tests were conducted on the same standard Dillon testing machine using either a 2500-lb. or a 5000-lb. dynamometer. Load readings could be taken to ±5 lb. The control system used to maintain a constant rate of strain throughout the duration of the tension type of test is shown in Fig. 1. Its chief component parts are:

(*a*) An SR-4 type A-1 resistance wire strain gage attached directly to the specimen;

(*b*) A $\frac{1}{4}$-in. thick 6-in. diameter rotating Lucite disk, driven by a Haydons timing motor, and containing on its outer surface a coil of alloy resistance wire, connected in series with the SR-4 strain gage mounted on the specimen;

(*c*) A contact spring connected to the measuring gage at one

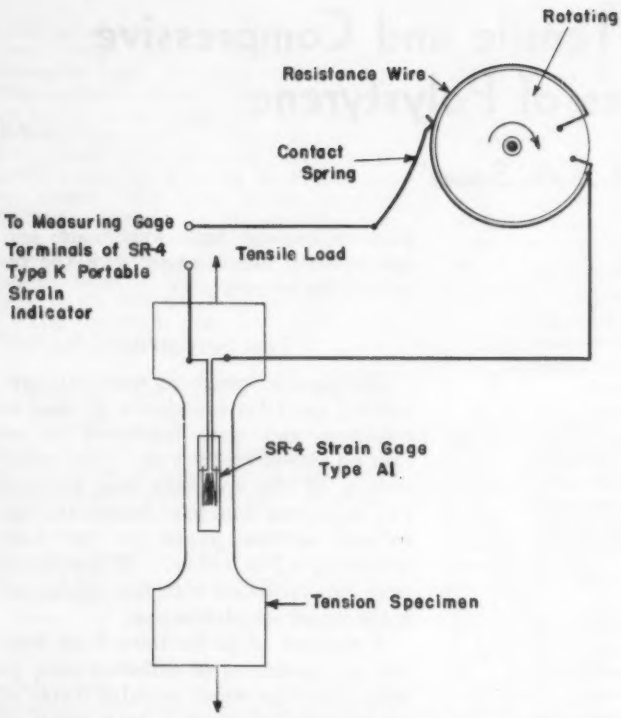

Fig. 1.—Schematic Diagram of the Control System for Constant Strain Rate in Tension Test.

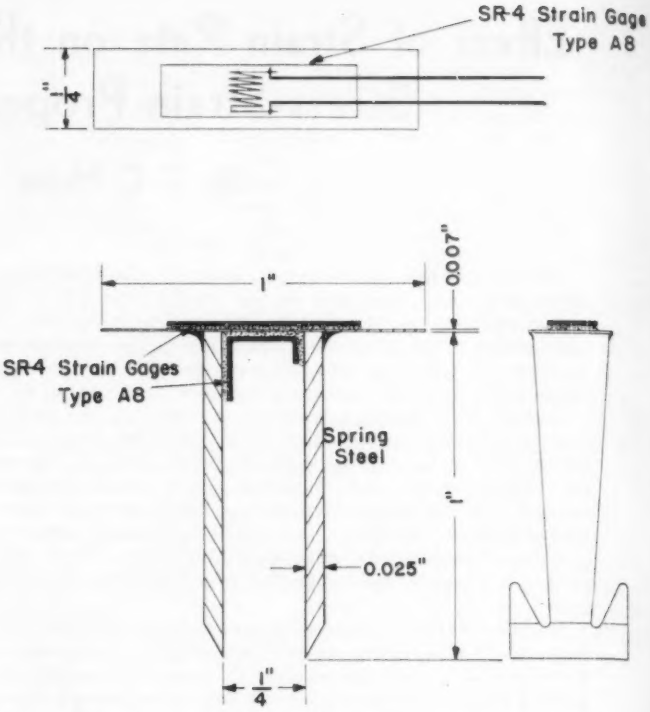

Fig. 2.—Schematic Diagram Showing Construction and Dimension of π Gage.

end and contacting the resistance wire on the rotating disk at the other; and

(*d*) An SR-4 type K portable strain indicator.

The control system operated as follows:

After the specimen was installed in the apparatus and ready for test, the timing motor on the Lucite disk was turned on. As the disk rotated, the resistance of the mounted wire was reduced at a predetermined rate. At the same time, tensile load was applied to the specimen at such a rate, controlled by hand, that the increase of the resistance of the strain gage would exactly balance the decrease of the resistance of the mounted wire in series with the strain gage. In other words, the total resistance of the control circuit was kept constant throughout the duration of the test.

Constant total resistance in the circuit was maintained by using the SR-4 type K portable strain indicator with a compensating resistance so that all the operator had to do was to keep the galvanometer balanced in its neutral position, by altering the rate of loading.

It should be mentioned that the strain recorded by the SR-4 gage is that based on a fixed initial gage length. However, for polystyrene the maximum fracture strain in tension is only about 1.5 per cent, and for an ultimate strain this small the value of the nominal strain is very close to the value of true strain based on the instantaneous gage length.

In the compression tests, some slight alterations in the control system were required. Direct attachment of the SR-4 gage to the specimen was not practical because of size limitations and range limitations. It appeared that more accurate results over a wider range of strain could be obtained if the strain gage was not directly attached to the specimen, but rather to a specially designed gage called the π gage, which itself contacted the specimen. The construction of the π gage is shown schematically in Fig. 2 and the control system itself in Fig. 3.

Basically, the π gage consisted of a π-shaped steel structure, containing a very

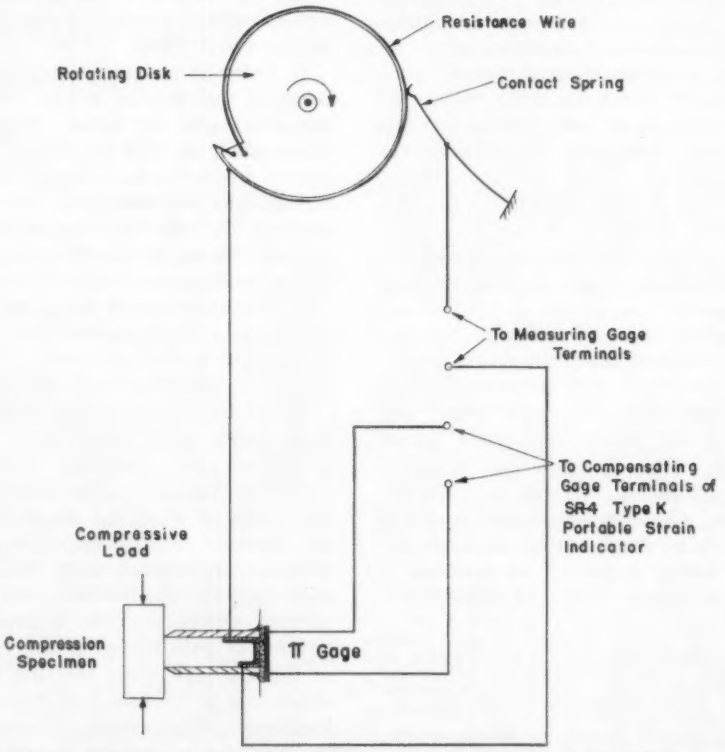

Fig. 3.—Schematic Diagram of the Control System for Variable Strain Rate in Compression Test.

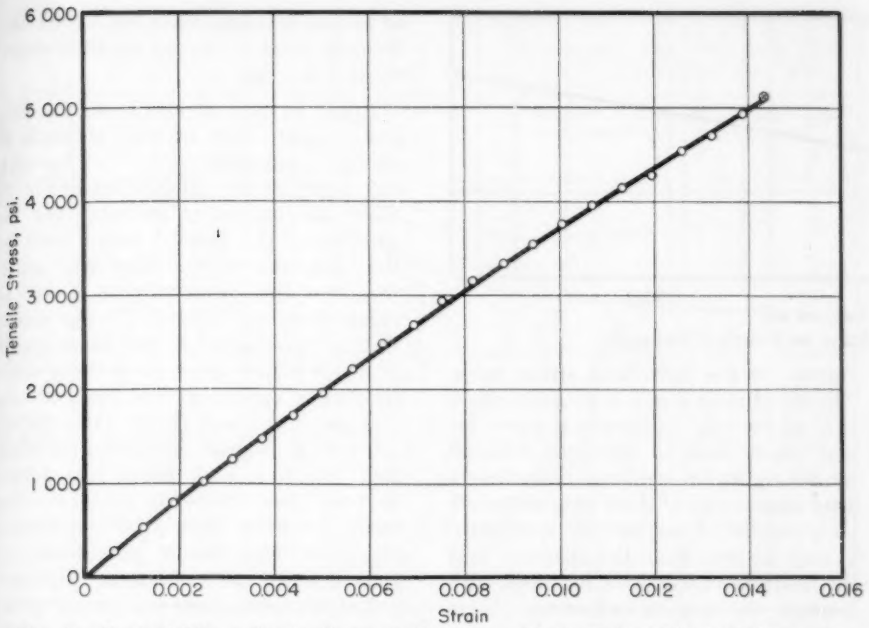

Fig. 4.—Typical Stress-Strain Curve in Tension. Strain Rate 5.25 $\times$ 10^{-6} per sec.

thin metal plate soldered to the flat ends of two steel arms. The other ends of the steel arms were shaped like knife edges so that there would be no slippage when they were held in contact with the surface of the compression specimen by means of an elastic thread. As the specimen was subjected to a compressive load, the knife edges of the π gage would move closer together, and a corresponding but much lesser change of strain would be recorded by the two attached type A-8 SR-4 gages on both the inner and outer surfaces of the top spring plate. The relation between the displacement of knife edges and the corresponding resistance change of the SR-4 strain gages was found to be essentially linear over a large range. For a gage length of $\frac{1}{4}$ in., use of the π gage extended the range of strain measurement to approximately 0.50 in. per in. The range can be extended even further to 100 or 200 per cent strain change by adjustment of the π-gage dimensions. A π gage of this type would also be helpful in extending the range of strain measurement for tensile loading, but for the polystyrene tension specimens it was not found necessary.

Two SR-4 strain gages rather than one were used to balance out resistance change due to variation of temperature and to increase the magnification of the strain reading. As in the tension tests, the resistance wire on the rotating disk was connected in series with one of the strain gages, and during operation of a test the sum of these two resistances was always kept in balance with that of the compensating resistance. A similar arrangement was used for strain-rate calibration measurements.

In compression tests, the circuit is therefore so connected that after the timing motor is turned on the resistance contributed by the resistance wire mounted on the rotating disk decreases at a constant rate and at the same rate as the resistance change produced in the circuit by the extension of the π gage increases.

For carrying out tests at constant strain rates based on a fixed initial gage length, a circular rotating disk mounted with uniform resistance wire is satisfactory. If, however, constant true strain rate based on instantaneous gage length is desired, a spiral disk designed to produce the desired variation of the resistance should be used. It is also possible to construct a disk with such a curvature that a tension or compression test could be carried out under variable rates of straining.

Calibration and Test Procedure

The strain rates used in the tension test were calibrated by use of the SR-4 strain indicator which recorded the change in resistance of the chromium alloy resistance wire as the disk on which it was mounted was rotated by the various timing motors. Thus, the change in resistance of this wire was obtained in terms of its corresponding strain quantities per unit time. Then, when the loading rate was adjusted to keep the strain indicator at a constant value, the specimen would automatically be strained at just that strain value previously calibrated.

The π gage used in the compression tests was calibrated by means of accurately machined standard blocks of different sizes and a portable SR-4 type K strain indicator. The blocks were used to record the distances between knife edges of the π gage, and the strain indicator to measure the corresponding strains. These readings could then be correlated to obtain a π-gage factor for the particular gage length chosen.

In the tension tests, the SR-4 strain gages were attached directly to the specimen by means of a specially prepared cement supplied by the Monsanto Chemical Co. Three coats of cement were used, each coat being allowed to dry before the next coat was put on. Usual procedures for attaching the gages were followed, and sufficient time was allowed prior to testing for the gages to stabilize. In the compression tests, the type A-8 strain gages were attached to the metallic π gage in the conventional manner, and the π gage, in turn,

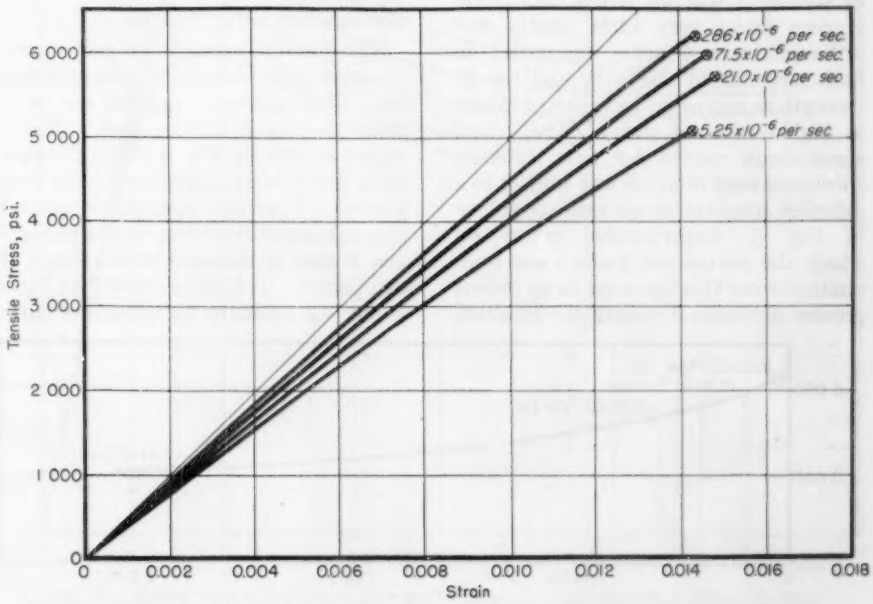

Fig. 5.—Stress-Strain Curves in Tension at Various Constant Rates of Straining.

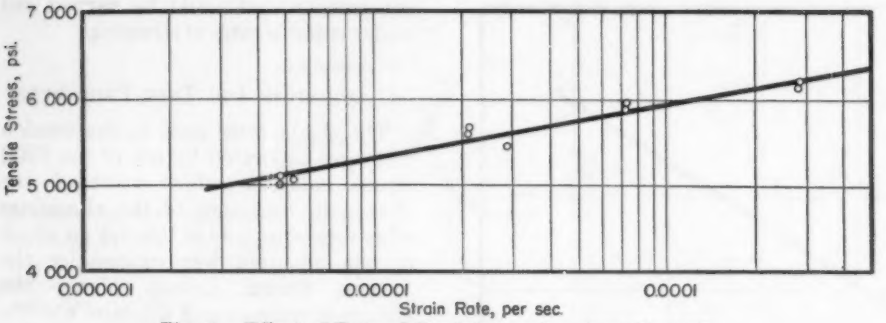

Fig. 6.—Effect of Rate of Straining on Fracture Strength.

was attached to the specimen by an elastic thread.

In both the tension and compression tests, the test operator acts as a servomechanism, continually making the necessary adjustments in rate of loading so as to maintain constant total resistance in the circuit. Timing motors of various speeds are used to provide the desired variation in rate of strain. The timing motor is started by an electric clock, and readings of load and time (and hence strain) are recorded at desired intervals up to fracture in the tension tests and up to 16 per cent strain change in the compression tests. In these latter tests, the change in the diameter of the specimen is also recorded simultaneously with other readings.

Tension Test Results

Tension tests were run on a number of polystyrene specimens at four different values of strain rate varying from 5.25×10^{-6} per sec., to 286×10^{-6} per sec. A typical tensile stress-strain curve for a strain rate of 5.25×10^{-6} per sec. is shown in Fig. 4. The open circles are the experimental points and the crossed circle represents the fracture point. Even for this rather slow rate of strain, it will be noted that polystyrene shows very little plastic flow although there is some diminution in both modulus of elasticity and tensile strength as compared to values obtained at higher rates of strain. The actual stress-strain curves for four different specimens each of which was subject to a different constant strain rate are shown in Fig. 5. Experimental points on which the curves are based have been omitted from this figure so as to permit greater delineation among the separate curves for the individual strain rates. The thin line of Fig. 5 is an approximation to the true stress-strain curve for very rapid rates of straining obtained by taking strain readings immediately after application of dead weight loading on a number of polystyrene specimens. It may be seen from this diagram that the modulus of elasticity increases with increase in rate of straining. More accurate data are needed to determine the specific amount of this increase, but as a rough approximation, it may be noted that each fourfold increase of strain rate corresponds to about a 4 or 5 per cent increase in modulus.

The fracture strength of polystyrene increases with increase in rate of straining. The increase appears to be a linear one on a semilog plot. This is shown clearly by Fig. 6 where the data from ten separate specimens have been plotted. Fracture strength is plotted also as a function of time of test in Fig. 7 and is seen to decrease with increase of test period. It is to be noted that Fig. 7 is not the ordinary time-fracture curve at various constant loads but is the time-fracture curve at various constant strain rates of testing.

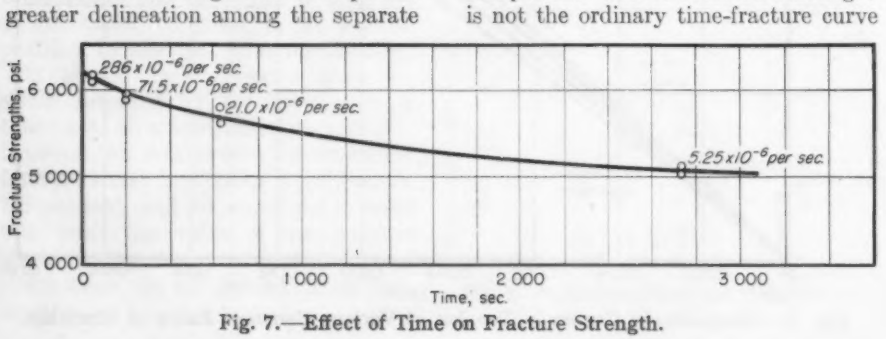

Fig. 7.—Effect of Time on Fracture Strength.

Effect of rate of strain on fracture strain rather than fracture strength is almost negligible. This is brought out clearly by the plotted data of Fig. 8. These results rather indicate that regardless of the rate of strain used in the particular test, failure will occur whenever the strain reaches a critical value (between 1.4 and 1.5 per cent). This is approximately the same strain at which failure under creep (long-time) conditions occurs, as has been shown in a previous report (5, 6). It is rather interesting to note in this connection that Maxwell and Rahm (9) found that for clean stress-free specimens the onset of crazing likewise always began, for given temperature conditions, at some definite value of strain. For cast polystyrene specimens at room temperatures they found crazing to first occur, or at least become significantly large, at a strain of 0.75 per cent.

Fig. 8.—Effect of Rate of Straining on Fracture Strain.

No significant difference was apparent in the nature of the fractures for the specimens subject to the widely different rates of strain. In all instances, the specimen fractured at right angles to the direction of applied tensile load and the fractured surfaces were very much like those previously described (5); namely, they exhibited fracture cracks radiating outward from the central source. The source was usually found to lie in the center of a small flat circular area, itself lying adjacent to a surface or within the otherwise amorphous fractured region. There was no necking down in any of the specimens and the only noticeable difference between specimens tested at the lowest strain rates and those tested at the highest strain rates was a very slight indication of crazing along the surface edges of the former group. Evidently, the slowest tests were just about slow enough to permit the crazing cracks to grow to visible size under action of the applied load.

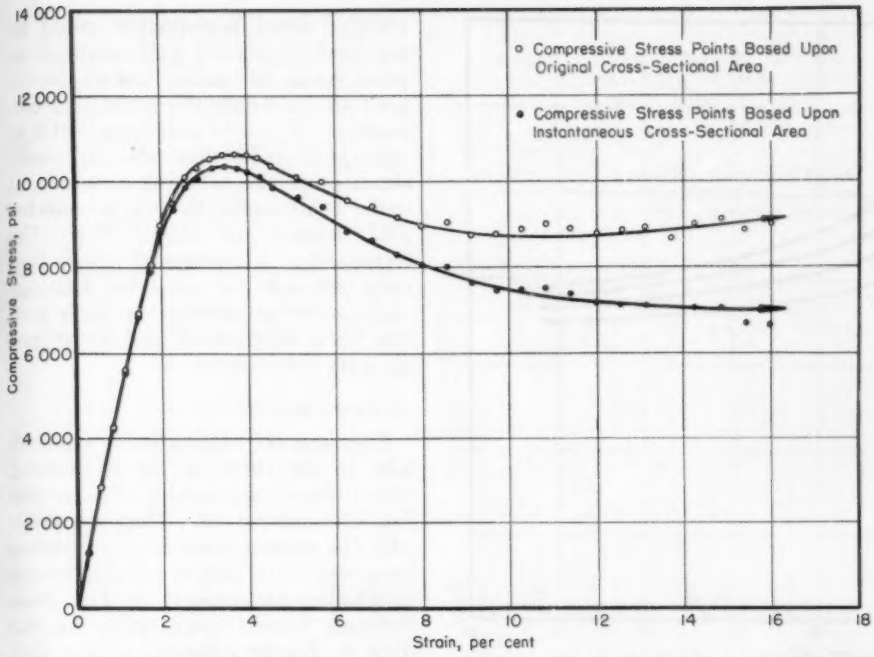
Compressive Stress Points Based Upon Original Cross-Sectional Area
Compressive Stress Points Based Upon Instantaneous Cross-Sectional Area
Compressive Stress, psi.
Strain, per cent

Fig. 9.—Typical Stress-Strain Curves in Compression. Strain Rate 11.9 × 10^{-6} per sec.

(Size of specimen 9/16 in. diam. by 1 in.) (π gage length, ¼ in.)

Compression Test Results

Typical compressive stress-strain curves for a polystyrene specimen are shown in Fig. 9 for both nominal stress based on original cross-sectional area and "true" stress based on instantaneous cross-sectional area. The curves shown are for a constant strain rate of 11.9 × 10^{-6} per sec. It will be noted that there is little difference between the nominal and the "true" stress until shortly before the maximum load is reached. It is at this point that uniform bulging of the round specimens begins to take place and hence the "true" stress falls increasingly below the nominal stress due to continued increase in cross-sectional area. This area is measured during progress of the test by micrometer readings of the diameter which are recorded along with the load and time (and hence strain) readings. After bulging starts, the actual state of stress is quite complicated and cannot be completely described by a single axial "true" compressive stress.

Tests were carried out at four different values of strain rate ranging from 11.9 × 10^{-6} to 712 × 10^{-6} per sec. The effect of strain rate change on the stress-strain properties of the material is shown by the graphs of Figs. 10 and 11 showing respectively load-strain graphs and "true" stress-strain graphs. As in the case of tension tests, the modulus of elasticity is seen to increase with increase of loading rate although the variation from one rate of straining to another is not quite so noticeable in Fig. 11 because of the larger scale used for strain. The approximate increase in modulus, however, is of the order of 2 to 3 per cent for a fourfold strain rate increase and hence is somewhat less than that noted for the corresponding strain rate change in tension.

Under compressive loading, the maximum load carried by the specimen and hence both the nominal and true stresses at this value of maximum load all increase with increase of rate of strain. Data show that a fourfold increase of strain rate produces an 8 to 10 per cent change in maximum load or maximum stress. Figure 12 shows that the increase of "true" compressive stress is a linear one when plotted against log of strain rate. The maximum compressive load or stress appears to occur at about the same value of "plastic" strain (1.3 per cent) regardless of the value of the strain rate. This is indicated by the dashed line of Fig. 11 and hence the "total" strain (elastic plus plastic) at the maximum load increases with increase of rate of strain.

Under compressive loading, fracture, as such, does not occur. Failure takes place by localized bulging of the specimen in the center region, the bulging first becoming noticeable after maximum load is reached. If greater and greater axial strains are applied to the specimen, longitudinal cracks open up along the circumference of the bulged section and usually some small crazing cracks become visible along the centerline of the round specimen and some distance inward from the top and bottom surfaces. These openings and cracks would appear to indicate the existence of tensile stresses sufficiently large to produce localized failure.

Discussion

Recently, the concept of the existence of a mechanical equation of state for solid materials has been revived (**10, 11, 12**). It is proposed, at least as a first approximation, that stress, σ, be considered a function only of the instantaneous values of plastic strain, ϵ, strain rate, $\dot{\epsilon}$, and temperature T. Thus, $\sigma = f(\epsilon, \dot{\epsilon}, T)$. This assumes

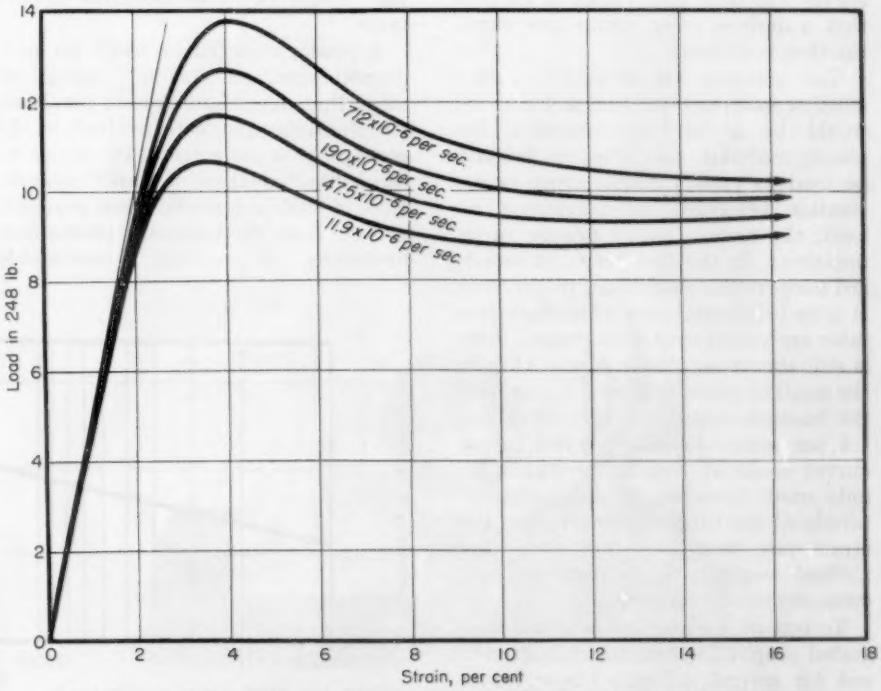

Fig. 10.—Load-Strain Curves in Compression at Various Constant Strain Rates.

(Size of specimen 9/16 in. diam. by 1 in.) (π gage length, ¼ in.)

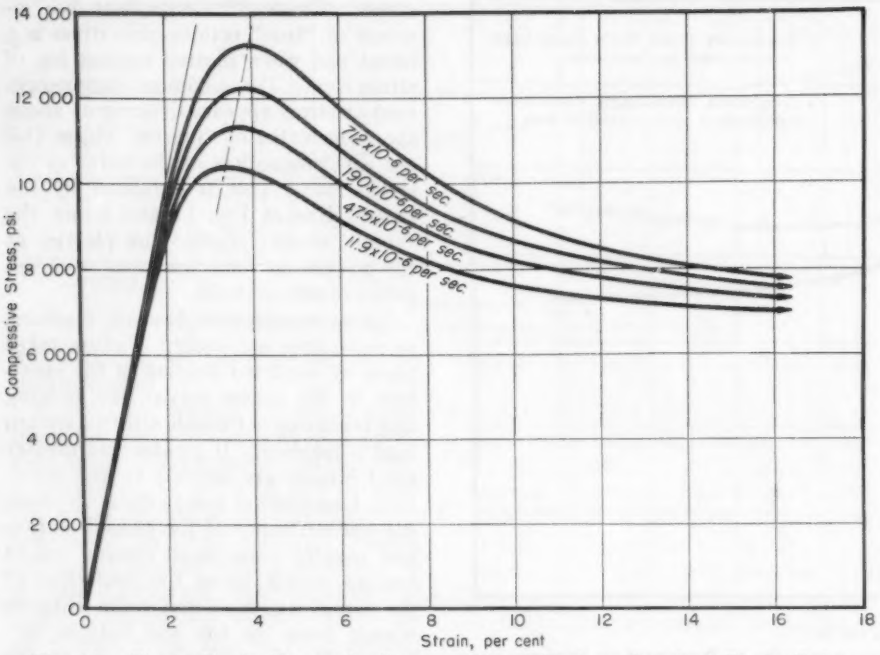

Fig. 11.—Stress-Strain Curves in Compression at Various Constant Strain Rates.

(Size of specimen 9/16 in. diam. by 1 in.) (π gage length, ¼ in.)

that prior strain history has no effect on the subsequent behavior and assumes also that time is not explicitly involved as a separate variable. If these conditions are met, then tensile-creep properties of the material can be derived from simple tension behavior under various constant strain rates. The required procedure is simply to use the stress-strain data at varying strain rates to plot graphs of the reciprocal of strain rate *versus* the strain. For given values of strain, the area under these curves will then give values of time so that a derived creep strain-time curve can then be plotted.

The question has frequently arisen whether some such relation as the above would be a fair approximation for plastic materials and whether it could be used to predict tensile creep or relaxation behavior. In polystrene, at least, the answer would appear to be negative. In the first place, at standard temperature conditions, polystyrene is quite brittle and even when the strain rates are varied over wide ranges, there is still almost no plastic flow. At even the smallest strain rate used in our tests the fracture strain was still only about 1.4 per cent. Because of this, creep curves could at best be predicted for only small times of the order of magnitude of the time required to run the strain rate test itself and hence the method would have no particular advantage even if applicable.

To test its possible validity, the suggested graphical procedure was carried out for several different stress values and the derived strain-time curves then compared with the known creep-time curves obtained previously (**4**, **7**). The "derived" curves, aside from their limited time range, did not correspond with the experimentally determined relations. An additional factor probably contributing to the failure of any such equation of state being applicable to polystyrene is the fact that "crazing" (**13**) of polystyrene is a time-dependent phenomenon. Therefore, no short-time tests in which this factor is relatively unimportant can be expected to provide long-time test information where "crazing" would be of considerable importance.

A plastic material in which no such phenomenon as "crazing," aging, or other time-dependent process involving structural changes, were involved, would perhaps be a more fortunate choice to check the "equation of state" concept. Even if such a material were available and did have the necessary plastic flow properties, it is still questionable whether creep performance could be accurately predicted, as dependence on prior strain or stress history would tend to invalidate the attempted correlation. It would also seem better to attempt to predict "compressive" stress-strain properties rather than tensile, as under compression there is a considerable amount of plastic flow. Unfortunately, experimental creep-time data are not yet available although equipment for carrying on such tests has been constructed and some preliminary tests started.

Acknowledgments:

The authors express their indebtedness to the Office of Naval Research under whose sponsorship this project has been carried on. They appreciate also the assistance rendered by various members of the staff of the Engineering Mechanics Department of The Pennsylvania State College, including Sam Eckley, Homer Johnson, George Cuff, Yoh-Han Pao, Steven Silwones, David Graf, and Miss Jean Richeson. In addition, the authors received the benefit of the advice and counsel of Joseph Marin of The Pennsylvania State College, of Edward Saibel of the Carnegie Institute of Technology, and of Howard Adams of the Monsanto Chemical Co.

REFERENCES

(1) C. W. MacGregor and J. C. Fisher, "Tension Tests at Constant True Strain Rates," *Journal Applied Mechanics, Transactions*, Am. Soc. Mechanical Engrs., Vol. 67, p. A-217 (1945).

(2) T. S. Carswell and H. K. Nason, "Effect of Environmental Conditions on the Mechanical Properties of Organic Plastics," Symposium on Plastics Am. Soc. Testing Mats., p. 22, (1944). (Issued as separate publication, *STP No. 59.*)

(3) A. G. H. Dietz, W. J. Gailus, and S. Yurenka, "Effect of Speed of Test Upon Strength Properties of Plastics," *Proceedings*, Am. Soc. Testing Mats., Vol. 48, p. 1160 (1948).

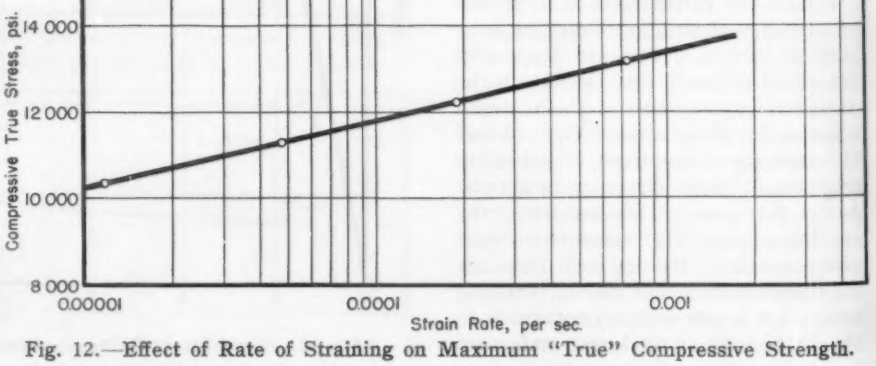

Fig. 12.—Effect of Rate of Straining on Maximum "True" Compressive Strength.

(Size of specimen 9/16 in. diam. by 1 in.) (π gage length, ¼ in.)

(4) J. Marin, "Creep-Time Relations for Polystyrene Under Tension, Bending, and Torsion," *Technical Report No. 1*, Office of Naval Research Contract No. N6onr-269, Task Order VI, July, 1948.
(5) J. A. Sauer, C. C. Hsiao, and W. J. Oliphant, "Elastic and Anelastic Properties of Polystyrene," *Technical Report No. 2*, ONR Contract No. N6onr-269, Task Order VI, January, 1949.
(6) J. A. Sauer, J. Marin, and C. C. Hsiao, "Creep and Damping Properties of Polystyrene," *Journal Applied Physics*, Vol. 20, No. 6, June, 1949, p. 507.
(7) J. Marin and G. E. Cuff, "Creep-Time Relations for Polystyrene Under Tension, Bending, and Torsion," *Proceedings*, Am. Soc. Testing Mats., Vol. 49, p. 1158 (1949).
(8) J. A. Sauer and W. J. Oliphant, "Damping and Resonant Load-Carrying Capacities of Polystyrene and Other High Polymers," *Proceedings*, Am. Soc. Testing Mats., Vol. 49, p. 1119 (1949).
(9) B. Maxwell and L. F. Rahm, "Rheological Properties of Polystyrene Below 80 C.," *Industrial and Engineering Chemistry*, Vol. 41, September, 1949, p. 1988.
(10) C. Zener and J. H. Hollomon, "Problems in Non-Elastic Deformation of Metals," *Journal Applied Physics*, Vol. 17, No. 2, February, 1946, p. 69.
(11) J. H. Hollomon, "The Mechanical Equation of State," *Technical Publication No. 2304*, Am. Inst. Mining and Metallurgical Engrs., November, 1946.
(12) J. H. Hollomon and J. D. Lubahn, "The Flow of Metals at Elevated Temperatures," *General Electric Review*, February and April, 1947.
(13) C. C. Hsiao and J. A. Sauer, 'On Crazing of Linear High Polymers," *Journal Applied Physics*, Vol. 21, No. 11, November, 1950, p. 1071.

Film Thickness Measurements

By E. J. Dunn, Jr.[1]

GROUP 11 of Subcommittee XVIII on Physical Properties of Materials of Committee D-1 on Paint, Varnish, Lacquer, and Related Products has developed two methods for the measurement of dry film thickness. The one, a method for the measurement of the dry film thickness of paint, varnish, lacquer, and related products which are 0.5 mil or greater in thickness, has been published as Tentative Method D 1005 – 49 T.[2] The second method which was accepted by Committee D-1 in June for submittal to letter ballot approval will measure films below 0.5 mil thick. The second method overlaps and supplements the first method.

INSTRUMENTS

There are a great many types of machines used for the measurement of film thickness of paint, varnish, lacquer, and related products. In the development work of the Tentative Method D 1005–49 T, eight different types of measuring instruments requiring various techniques were studied A short description of these instruments and techniques follows.

One film thickness gage based upon the magnetic principle of measurement is the Magne Gage (Fig. 1). Essentially this instrument consists of a small permanent bar magnet 0.08 in. (2 mm.) in diameter, freely suspended from a horizontal lever arm. The lever arm is actuated by a spiral spring which is coiled by turning a graduated dial. The attractive force between the magnet and the specimen is balanced against the spring tension as indicated on the graduated dial. The readings obtained are related to the magnetic reluctance introduced by the film and can be converted to film thickness by reference to calibration curves supplied with the instrument. The instrument is adapted to various applications and thicknesses by means of readily interchangeable magnets which differ principally in size and strength.

During the last year, two small portable film thickness machines have come to the committee's attention based on the magnetic principle, namely, the

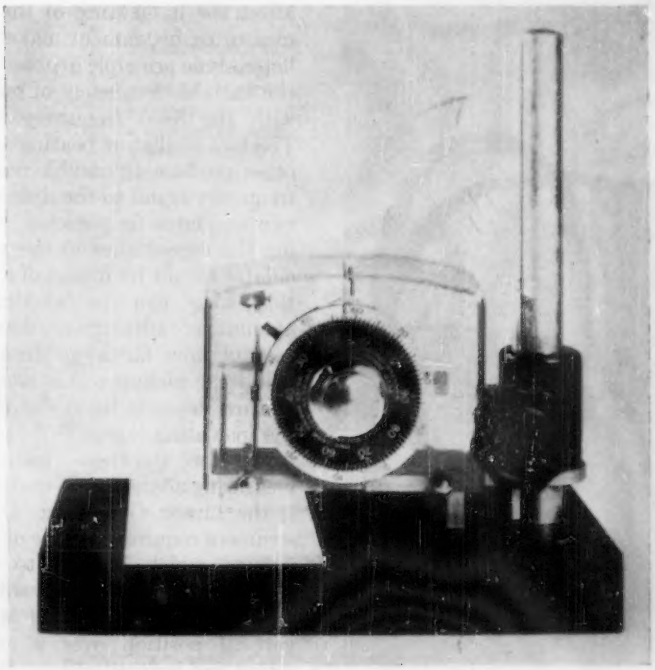

Fig. 1.—Magne Gage.

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[1] National Lead Company, Research Laboratories, 105 York St., Brooklyn, N. Y.; Chairman, Group 11, Subcommittee XVIII, Committee D-1.

[2] Tentative Method for Measurement of Dry Film Thickness of Paint, Varnish, Lacquer, and Related Products (D 1005 – 49 T), 1949 Book of ASTM Standards, Part 4, p. 448.

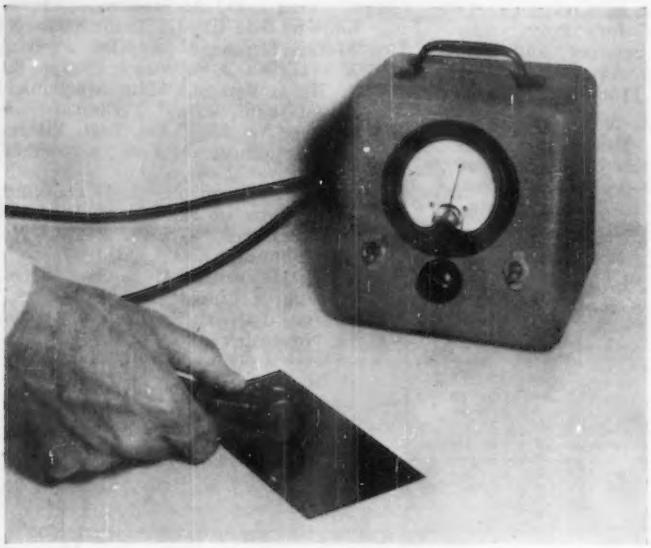

Fig. 2.—General Electric Gage.

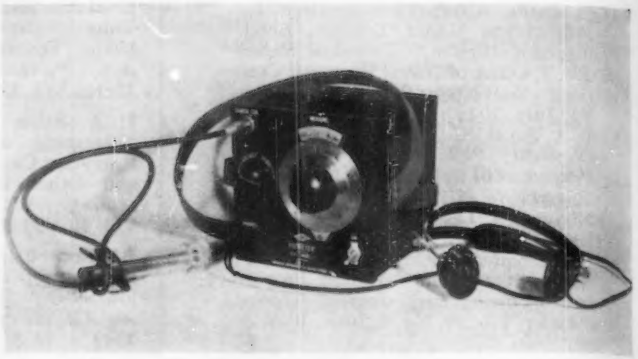

Fig. 3.—Filmeter.

Krouse Machine and the Elcometer.

Another film thickness instrument used in our committee work is the General Electric Gage (Fig. 2). This operates on the principle that any nonmagnetic material applied to an iron or steel base is equivalent to an air gap interposed between the magnetic base and the two magnetic pole tips, or flanges, of the gage-head. When the pole tips, or flanges, of the gage-head are placed against the surface of the nonmagnetic material, the magnetizing current in the gage-head coil sets up a magnetic flux which "threads" through the iron core of the gage-head, across the two small gaps imposed by the nonmagnetic material, and through the steel base material. The reluctance of this flux path is predominantly a function of the length of the gap in the magnetic circuit, and the electric impedance of the gage-head varies as a function of the air-gap length or the thickness of the nonmagnetic film material. This machine is usually calibrated with sheets of cellophane or celluloid of known thicknesses.

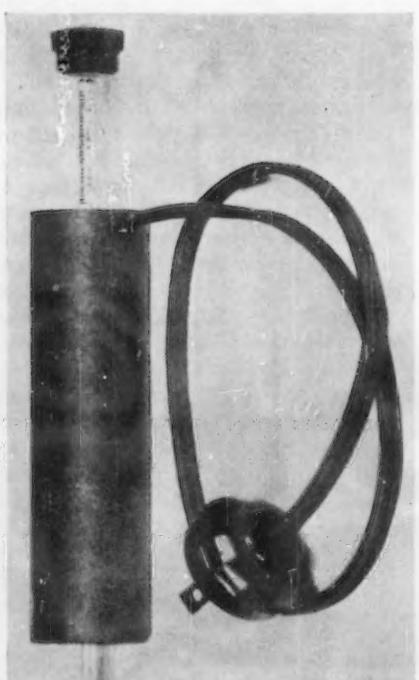

Fig. 4.—Lipson Gage.

The Filmeter is an instrument used to measure the film thickness of nonmagnetic materials applied to a nonmagnetic base (Fig. 3). This instrument is based upon the phenomenon that when a-c. current flows in a coil near the surface of a nonmagnetic metal, eddy currents are set up in the metal which affect the inductance of the coil. The measuring instrument makes use of the heterodyne principle in order to compare the variable frequency of one oscillator with the fixed frequency of another. The two oscillators beating against each other produce an audible note having a frequency equal to the difference of the two oscillator frequencies. By adjusting the capacitance in the variable oscillator circuit by means of a condenser, this tone can be eliminated. The amount of adjustment depends upon exactly how far away from the base metal the pickup coil is located, which in turn depends upon the thickness of the insulating layer.

A film thickness instrument for measuring nonmagnetic coatings on steel is the Lipson Gage (Fig. 4). This instrument requires a source of alternating current which is used to energize a solenoid containing a movable iron core. If the energized solenoid is held in a vertical position over a coated steel article and lowered sufficiently to permit the lower end of the core to contact the surface, the distance through which it may be raised for the pull of the solenoid to overcome the attraction of the core for the base metal will vary inversely with the thickness of the coating.

Two types of electronic micrometers were used in this cooperative study. One is the R. W. Carson micrometer, and the other was the Jack & Heintz electronic micrometer. These instruments are designed to give precise measurements of film thickness. Three members of our committee have the R. W. Carson electronic micrometer so considerably more data were collected with this instrument (Fig. 5). For paint films, the manufacturer recommends an anvil diameter of $\frac{1}{8}$-in. and the anvil load of 4 oz. which is equivalent to a unit pressure of 20.5 psi. This is a very light load and comes within the specifications for micrometers considered satisfactory for measuring the film thickness of organic coatings. This micrometer has an electronic attachment to make a sharp contact with the metal. A bulb lights up so the operator knows contact has been established. An accuracy of the micrometer screw is

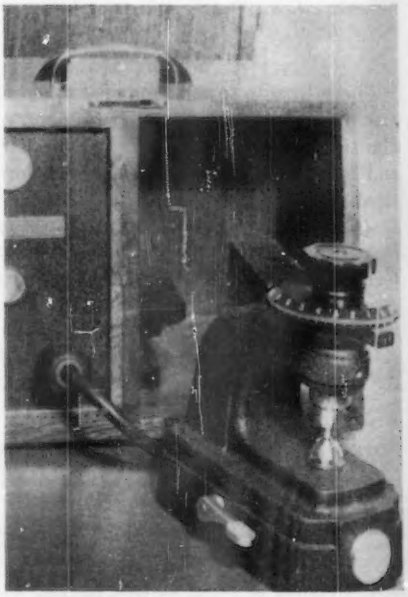

Fig. 5.—Electronic Micrometer.

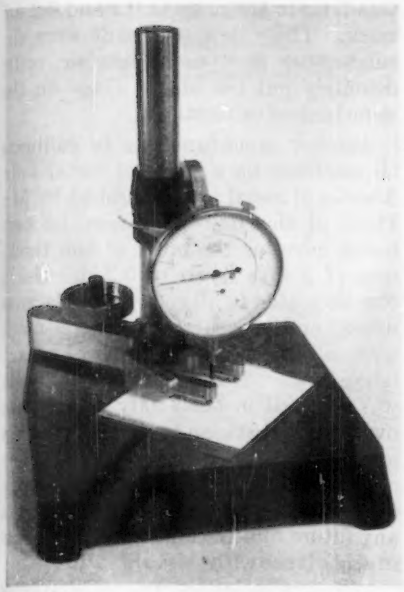

Fig. 6.—Dial Micrometer.

claimed to better than 0.000010 in. for a dial increment of 0.005 in. or less. To keep panels rigid, it has a hold-down attachment which is supplied as a standard attachment for making paint film thickness measurements.

Another method used was the measurement of the cross-section of the paint film by mounting specimens for microscopic examination. This method is quite satisfactory for many specimens, but when samples are mounted on metal it is often difficult to obtain cross-sections. If the film is on tin plate, it may be readily removed with mercury and mounted under the microscope. This method has merit, but it appears the results obtained are somewhat dependent upon the technique of the mounting, and the operator, and, therefore, this method was not considered an ideal type for an ASTM method.

One technique which was used in some of the work was the determination of the weight of paint over a given area. If the specific gravity of the paint is accurately known, a calculation can be made of the film thickness applied. Although this method is used in the industry for certain indirect types of control on coatings, it was not given very enthusiastic support in our original work on film thickness measurements.

The final instrument or technique used in the first phase of the committee work was the micrometer measurement. Initially, various types of micrometers and micrometer-heads were used, but it was decided a micrometer of the dial type was most suitable for the purpose (Fig. 6). Such an instrument should have a 4-in. dial which is large enough to be read directly to 0.0001 in., and an estimate can be made to the nearest 0.00001 in. This is the type described in ASTM Tentative Method D 1005-49 T. The pressure foot or that part of the micrometer contacting the film is limited from $\frac{1}{16}$ to $\frac{1}{8}$ in. in diameter and is flat on the bottom. The load on the presser foot is restricted between 20 and 40 psi. This instrument meets the specifications for micrometers described in ASTM Method D 374.[3]

When such a gage is used to measure film thickness to 0.0001 in., it is necessary to have a satisfactory means for holding the panel in place. The equipment in Fig. 6 is one representative type for the purpose. Other types are used in industry and have been found to be equally satisfactory.

Measurements Above 0.5 Mil

With all these instruments available, a "round robin" of film thickness measurements was made on six panels representing measurements on three types of organic coatings and four different types of application. These coatings were applied by a dip coater, inclined doctor blade, automatic spray, and by roller coater. An individual set of panels was forwarded to each of seven laboratories. Each laboratory was requested to make measurements with as many instruments or techniques readily available at their laboratory. Figure 7 illustrates the character of the results obtained. Considering that no limitations as to methods of measurement, techniques of calibrating instruments, or differences in panel preparation were prescribed, the committee felt that a good set of data was obtained in this first series of "round-robin" results. It is evident from the chart that there is an indication of part of the data following a pattern. Certain laboratories' data were higher than others. When such a pattern is obtained, it seems to be a question of calibration of equipment. In this series, the General Electric Gage results were more erratic than the Magne Gage results. Microscopic measurements agree quite closely with the micrometer measurements for the thicker films. However, in the case of the thinner films, the microscope seemed to give high results. The micrometer values were a good average of all the values.

With these data available from seven different laboratories covering six different techniques, the committee tried to decide what accuracy would be acceptable for this film thickness work. For most work, it was felt that results within ±0.1 mil, were adequate. Methods were then prepared based on four of the machines, and in discussing them, the suggestion was made that practically all laboratories have or could afford a dial micrometer. Therefore, it was decided to use the micrometer as the basis for comparing or calibrating other film thickness machines. This basic decision allowed the work of the committee to progress at a faster pace. It should be added that this does not preclude the use of the other nondestructive machines, but if there is a discrepancy, the calibration should be made against a micrometer meeting the

[3] Methods of Test for Thickness of Solid Electrical Insulation (D 374 – 42), 1949 Book of ASTM Standards, Part 4, p. 871.

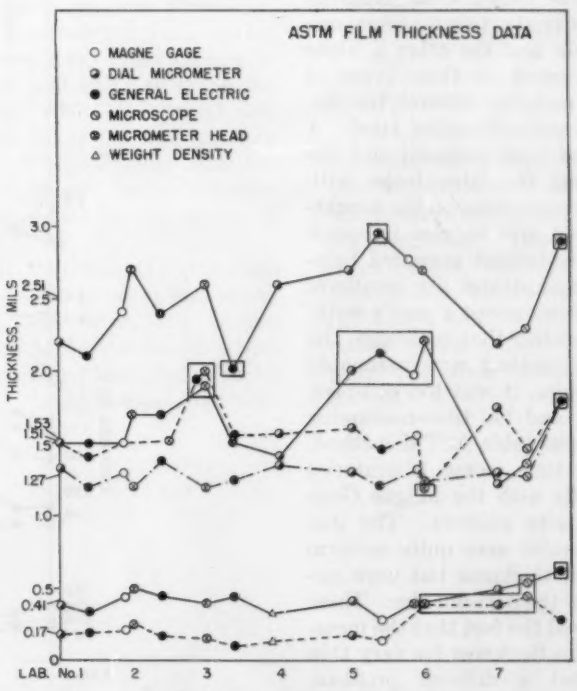

Fig. 7.—First Cooperative Series.

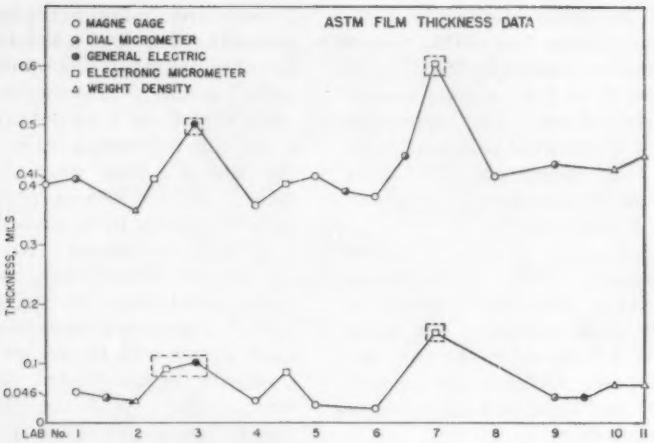

Fig. 8.—Second Cooperative Series.

requirements of Method D 1005–49 T. In accordance with this decision, a tentative film thickness method based upon the dial micrometer was prepared and subsequently accepted by Committee D-1.

Weight Density Method

The second phase of this work was based on the measurement of films below 0.5 mil thick. It appeared the main interest for such measurement centered around lithographic coatings and can coatings. It was, therefore, decided to have a group of approximately ten members take on the task of measuring the film thickness and to have a portion of the group concentrate on the weight-density measurement method since the weight-density method was favored by the lithographic coatings group. Accordingly, two coatings, one a clear phenolic and the other a white alkyd, were spread on three types of base stock, namely, electrolytic tin, bonderite K, and cold-rolled steel. A series of panels were prepared and distributed among ten laboratories with the idea of concentrating on the weight-density method and to also use such auxiliary methods that appeared helpful. Figure 8 illustrates the results of this study. After about a year's work, the group decided that although the weight-density method gave reasonably consistent results, it was too complex, too laborious, and too time-consuming to make an acceptable ASTM method. At the same time, some laboratories reported results with the Magne Gage which were quite uniform. The dial micrometer results were quite uniform for the 0.4-mil thickness but were unsatisfactory for the 0.05-mil film. These data emphasized the fact that the measurement of film thickness for very thin films presented a difficult problem. It might be added that several laboratories had difficulty making these measurements.

Calibration of Equipment

On further discussion, it was decided to attempt to standardize the various instruments used in our previous work so that all the various laboratories could measure the same sample and calibrate their machines according to standards to be distributed. Two procedures of standardization were selected. For those laboratories having the Magne Gage, the National Bureau of Standards volunteered, through the efforts of Mr. Blum, to prepare another series of calibrated standards, primarily to cover thin films in the order of 0.1 and 0.2 mil thick. These new standards were circulated so that each member could definitely put his Magne Gage on the same basis of calibration.

Another procedure was to calibrate all machines on a series of metal foils. A series of metal foils, furnished by Mr. Phair of the Bell Telephone Laboratories, covering the range of film thickness of 3 mils down to 0.2 mil thick, was circulated to all cooperating laboratories, and measurements were made with all machines available to each laboratory. A large amount of data was received in this study and turned over to a statistician to designate a best average value to use for each foil. Each committee member was then requested to accept this calibration and to correct any future film-thickness measurements in accordance with this calibration.

Figure 9 illustrates the character of the results obtained on these foils. It is evident from the data that the dial indicator has given very consistent results. The group accordingly felt that its previous decision that the micrometer gage was one of the simplest and best means of calibrating film thickness measurement machines was sound. The results with the Magne Gage were quite satisfactory, but occasionally the Magne Gage would show an erratic value. A suggestion was received from Mr. Malone of the Western Electric Co. that a string release, together with a motor drive to free the magnet of the

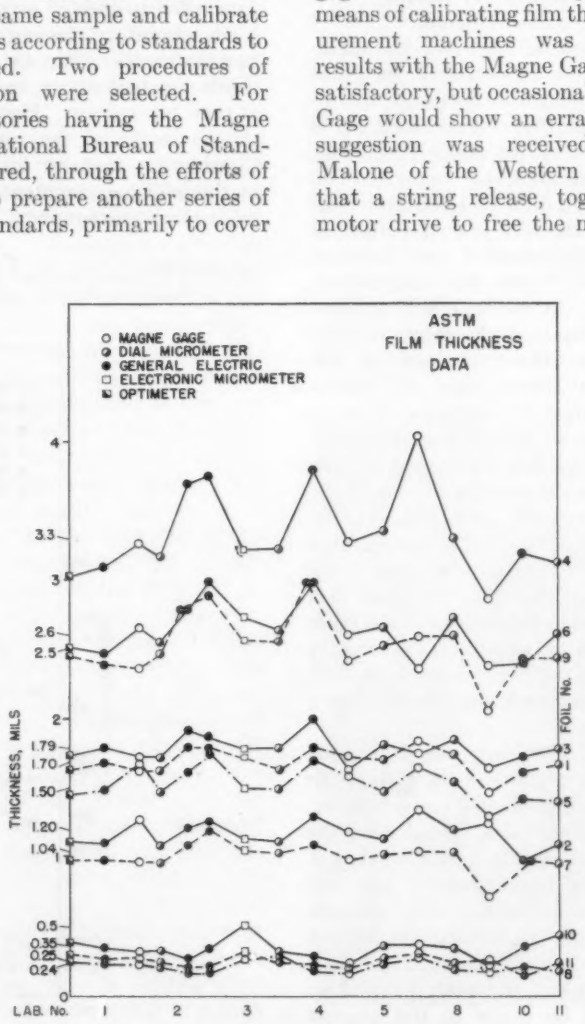

Fig. 9.—Calibration with Metal Foils.

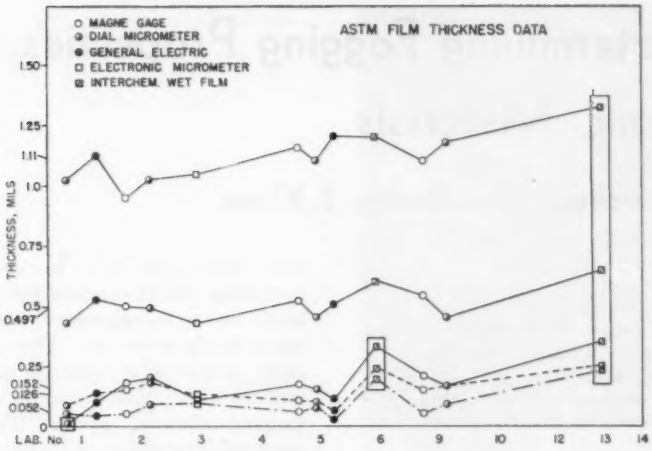

Fig. 10.—Fourth "Round-Robin" Series.

Magne Gage and also mounting the machine on a vibradamp base, as used by them, helped to unify the release of the magnet from the film and thus give more consistent results.

It was also evident in this series that the results with the General Electric Gage were inclined to be high. This was especially true in some laboratories, indicating that a better calibration would bring the particular machine into line. Results with the electronic micrometer are quite similar to the dial micrometer gage values, especially for films above 0.5 mil. The optimeter values closely approximated results with the dial micrometer. In view of all the above measurements, it appeared that the various film thickness machines could be calibrated to give the same film-thickness measurements.

Measurements Below 0.5 Mil

Following this preliminary calibration work, a specially prepared series of panels was prepared, through the efforts of Mr. Loy Engle of the Interchemical Corp. The panels were taken from an actual production coating schedule in which the film thickness was varied from 0.5 mil down to 0.1 mil thick. Five different types of coatings were used for the purpose, and all the coatings were applied on three types of stock, namely, tin plate, bonderite K, and cold-rolled steel.

A "round-robin" series of results were obtained from twelve laboratories using five different film-thickness machines. In this series of tests, an additional machine was included, namely, the Interchemical Wet Film Thickness Gage. The wet film thickness gage was adapted to dry film thickness measurements. The results of this "round-robin" series of data are illustrated in Fig. 10. By studying this chart, it is evident that certain of the data appear to be off. Such data have been enclosed with squares or rectangles. By using these data and the data from a subsequent chart, a grand average of values was obtained. Taking into consideration all the problems of calibration, variation of panel preparation, and coordination of various laboratories, it appears that this correlation of results is satisfactory. Results with the Interchemical Wet Film Thickness Gage were consistent, but for those films below 0.5 mil, results were on the high side. This appears to be a matter of calibration to bring the results in line with other machines. Measurements below 0.1 and possibly 0.2 mil are not reproducible with the dial type micrometer. Difficulties arise with most machines in this range of measurement.

In this study, the General Electric Gage gave results almost as consistent as the Magne Gage. However, the Magne Gage appeared to be the machine that gave the most consistent results in all four series of "round-robin" measurements. In view of this, it was decided that the supplementary method to Method D 1005–49 T should be based upon the Magne Gage. Accordingly, a proposed tentative method was prepared and is in the process of being considered by Committee D-1.

A word of caution should be made at this time. Film thickness measurement of very thin films is a difficult problem, and proper techniques have to be applied to the use of any method. Tacky films, for instance, cause magnets to stick, and such films might be compressed by micrometer spindles. Some precautionary information is included in the use of these methods.

A third assignment for our committee is the consideration of a method for wet film thickness measurements. The committee eventually will conduct some cooperative work to try to develop a suitable ASTM wet film thickness method.

Cooperators in this film thickness work were:

L. S. Engle—Interchemical Corp.
E. R. Stacy—American Cyanamid Co.
H. D. Pharo—American Cyanamid Co.
R. J. Phair—Bell Telephone Laboratories
C. C. Hipkins—Bell Telephone Laboratories
M. G. Bell—Ditzler Color Division
F. C. Schmutz—New Jersey Zinc Co. (of Pa.)
A. E. Jacobsen—National Lead Co.
J. A. Boylan—Parker Rust Proof Co.
E. T. Fitzgerald—E. I. du Pont de Nemours and Co., Inc.
M. R. Euverard—Interchemical Corp.
H. E. Malone—Western Electric Co.
G. G. Sward—National Paint, Varnish and Lacquer Assn.
M. H. Switzer—Continental Can Co.
A. L. Alexander—U. S. Naval Research Laboratory
E. J. Dunn, Jr.—National Lead Company

Acknowledgment:

The efforts of Mr. Blum of the National Bureau of Standards in producing new standards for calibration of the Magne Gage were greatly appreciated by our committee. The metal foils loaned to us by Mr. Phair of Bell Telephone Laboratories most certainly aided our calibration work, and the panel preparation by Mr. Engle of Interchemical Corp. helped to make our program a success.

A Test Method for Determining Fogging Properties of Organic Materials

By Vincent J. Marchese[1] and Stanley J. Klima[1]

SYNOPSIS

Operating temperatures of equipment often reach the level at which their structural organic materials decompose liberating vapors which condense on cooler portions of the equipment causing a condition known as fogging. Fogging may introduce undesirable equipment malfunctioning or interrupt service. This paper describes a test apparatus and method for determining the fogging characteristics of organic materials, and presents results of tests on a variety of materials.

IN THE past few years, engineers have encountered an elusive materials - application problem commonly referred to as fogging, that is, the condensation of vapors on cold surfaces, such as instrument dials and optical components or internal parts, which impairs the reading or correct operation of the instrument. Investigations reported in the literature have been primarily in the field of fogging of aircraft windshields where water droplets are condensed on the surface of the windshield and other vision devices from air at a temperature above the dewpoint upon surfaces which are below the dewpoint temperature.[2] Various "anti-mistants," which fall into the class known as synthetic wetting agents, have been suggested by Main-Smith[3], and E. A. Vitalis[4] and the National Research Corp.[2] for the prevention of fogging by reducing the surface tension of the glass sufficiently to permit the formation of clear water films. The current investigation has been concerned with the fogging produced by condensable vapors driven off from organic materials under conditions of high ambient temperature. Seymour[5] found that the type of decomposition products obtained in the pyrolysis of polymeric hydrocarbons was a function of the structure of the hydrocarbon chain and the volatility of the products of pyrolysis. Rosen and Thomas[6] found that the addition of small amounts of aromatic compounds of a "phenolic" nature delays the rate at which polymers decompose at any temperature.

Several methods of test for evaluating the fogging characteristics of organic materials were investigated. The inconsistency of these methods led the Materials Laboratory to develop a new test procedure and associated equipment which greatly improve the reproducibility of results. A technique was also developed to give a permanent photographic record of the fog deposit produced.

THE PROBLEM

A number of organic materials such as oils, greases, insulating tubings, impregnating varnishes, etc., are used in practically all Sperry equipment. These materials when used under low-temperature conditions usually perform their intended functions satisfactorily. However if temperatures are allowed to rise (usually to 82 C. (180 F.) or above depending on the organic material) these materials begin to break down chemically, liberating vapors which sometimes are corrosive. These vapors condense on cooler parts of the equipment causing considerable trouble through fogged optics, fouled slip-rings, or increased resistance of low-pressure electrical contacts. In evacuated gyro systems fogging is further aggravated because the decomposition and vaporization temperatures of these organic materials are lowered. As a result the vacuum is soon lost under fairly low-temperature operating conditions and the gyro overheats due to increased windage and failure is likely to occur. Dye and Koopman[7] suggested a moisture control system for aircraft instruments containing vacuum-operated gyros. The system consisted of a perforated tube surrounded by silica gel crystals and the whole inclosed by a heating coil.

APPARATUS

The test apparatus developed by the Materials Laboratory for evaluating the fogging properties of organic materials simulates the material application conditions since essentially the method consists of heating a sample of the test material and condensing the liberated vapors on a cool surface.

The test apparatus consists of an oil bath maintained at 82 ± 0.5 C. (180 F.), a constant temperature water-circulating system maintained at 15 ±0.5 C. (59 F.), and the test cells in which the sample is heated and the vapors are condensed (see Figs. 1 and 2).

The size of the sample to be used is varied somewhat with the material. For oils, greases, and potting compounds

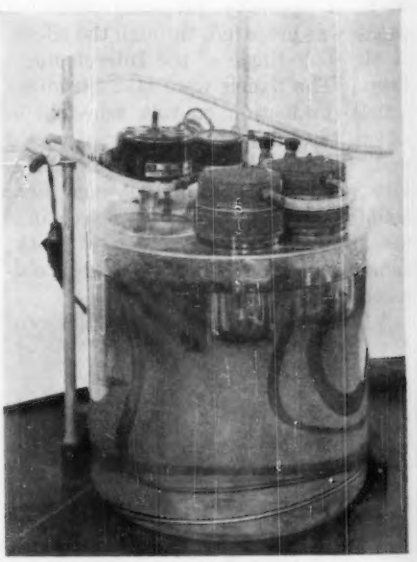

Fig. 1.—Apparatus in Materials Laboratory for Obtaining Data on Fogging Characteristics of Samples.

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[1] Leader of the Chemical Group and Chemist, respectively, Sperry Gyroscope Co., Great Neck, L. I., N. Y.

[2] National Research Corporation, "Fogging of Vision Devices Under Flight Condition" (OSRD Report 894), n.d. 9 p.; obtainable from the U. S. Department of Commerce, Office of Technical Services as PB 23766.

[3] J. D. Main-Smith, and J. Darge, "Anti-Misting Agents for Aircraft," *Chemistry and Industry*, Nos. 8, 9, 10, February 22, March 1 and 8, 1947, pp. 107–108.

[4] E. A. Vitalis, "Anti-fogging Composition," U. S. Patent No. 2,414,074 (1947).

[5] R. B. Seymour, "Pyrolysis of High Polymeric Hydrocarbons," *Industrial and Engineering Chemistry*, Vol. 40, pp. 524–527 (1948).

[6] R. Rosen and R. M. Thomas, "Polymer Composition," U. S. Patent No. 2,244,021 (1941).

[7] E. R. Dye and R. J. W. Koopman, "A Moisture-Control System for Aircraft Instruments Containing Vacuum Operated Gyros," *Instruments*, Vol. 19, pp. 400–401 (1946).

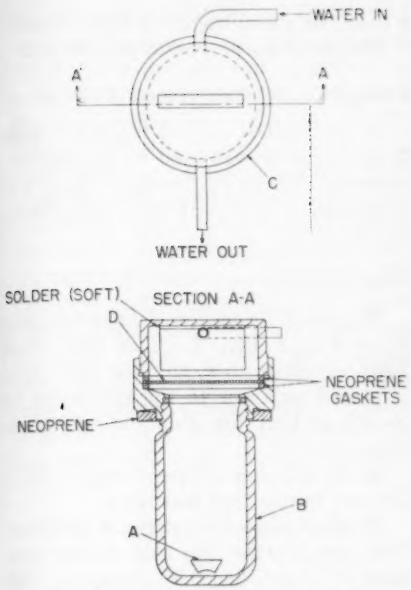

Fig. 2.—Cooling Chamber for the Fogging Apparatus.

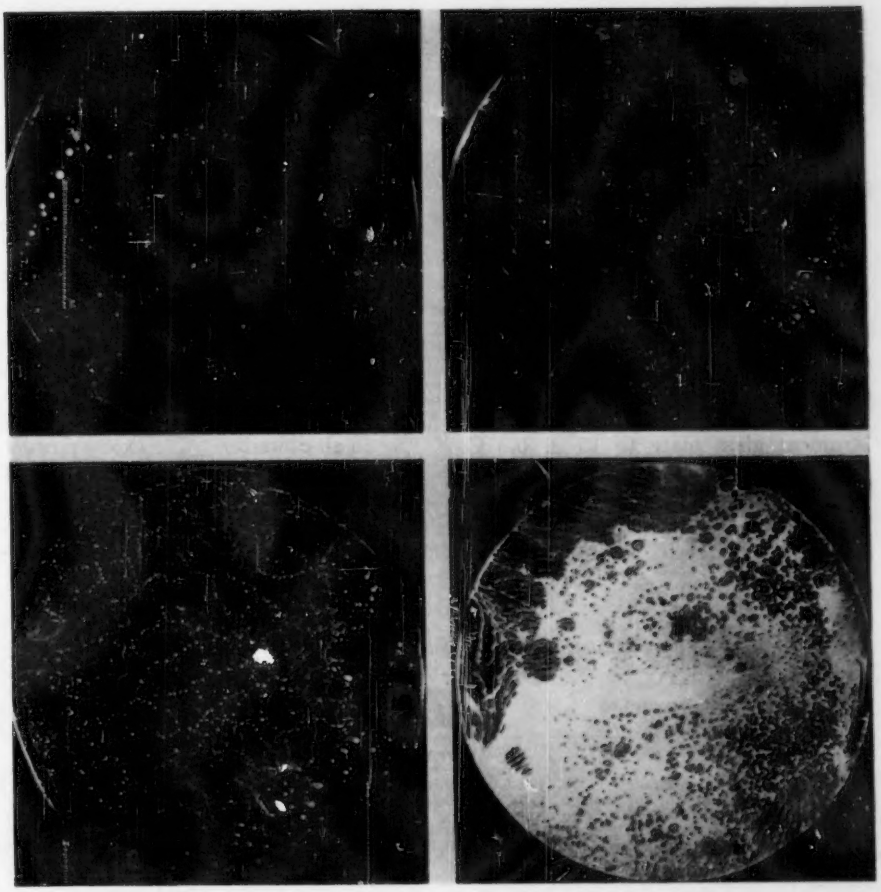

Fig. 4.—Plates Showing Variation of the Powder Retention on Glass Plates After Immersion in Oil-Solvent Solutions of Varying Percentage.

0.1 per cent (*upper left*); 0.25 per cent (*upper right*); 0.5 per cent (*lower left*); 1 per cent (*lower right*).

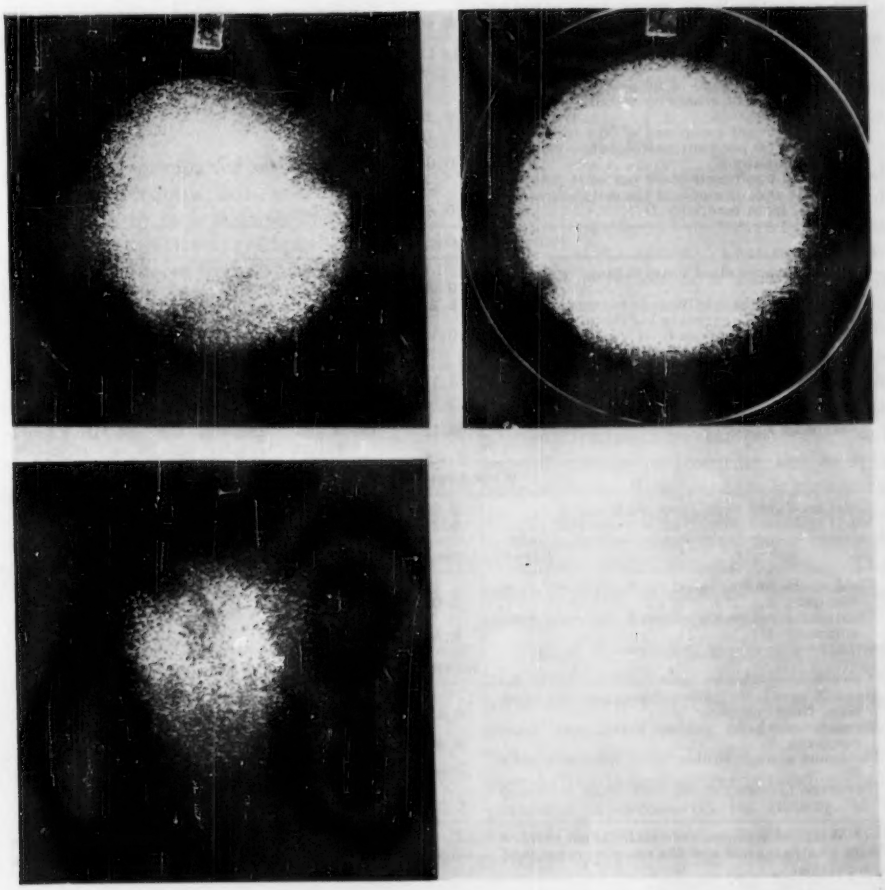

Fig. 5.—Fogging Characteristics of Typical Materials.

Polyester resin saturated Fiberglas tubing (*upper left*), grade A, from company *H*; same tubing (*upper right*), grade B; the silicone saturated Fiberglas sleeving (*lower left*) from company *I*.

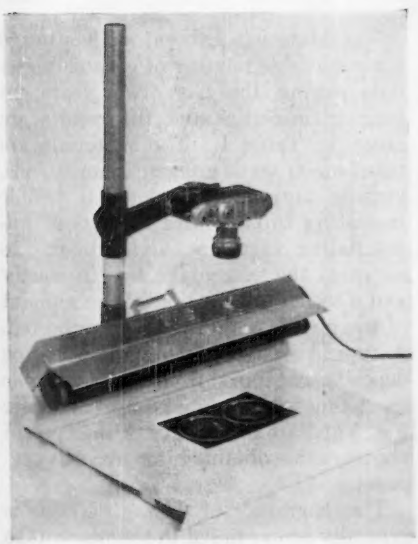

Fig. 3.—Photographic Part of Fogging Test Apparatus.

300 mg. of sample are used; for wire insulation, 500 mg. of sample are used; and for organic finishes and impregnating compounds, actual sample pieces are used.

A platinum crucible containing the sample *A* is placed in a 4-oz. (fluid), screw-top jar *B* (Fig. 2) which is immersed in the temperature-regulated oil bath. The jar is covered by means of a cell *C* which contains an instrument glass plate *D* ($\frac{1}{16}$ in. thick and 3 in. diam.) sealed with sulfur-free neoprene gaskets. Water from a constant-temperature circulating system enters the top section of the cell and cools the instrument glass plate to 15 ± 0.5 C. Vapors from the samples are condensed on the underside of the glass so that comparative fogging characteristics can be made.

Test Procedure

The sample to be checked for fogging properties is weighed accurately in the platinum crucible and placed in the 4-oz. jar immersed in the oil bath. The test is run for 16 hr. during which time any vapors from the sample are condensed on the cooled glass plate. At the completion of the test, the cell is opened and the sample is weighed and percentage loss in weight calculated.

In order to obtain a permanent photographic record of the fog, the deposit on the glass plate is first dusted with a phosphorescent luminescent powder using an air atomizer. The excess powder is removed by means of an air blast set at 40 psi. with the nozzle fixed at approximately one foot from the glass plate. Photographs are then obtained by exposure to an ultraviolet light source.

Details of the process appear below:

Phosphorescent Luminescent Powder:

A zinc sulfide (nonradioactive) pale green pigment was used as the dusting powder. It can be procured from the Luminous Products Co., Great Neck, N. Y.

Photo Conditions:

The setup for taking the photographs is shown in Fig. 3. The ultraviolet light source, a 15-w. tubular unit type, is placed adjacent to the specimens as shown so that the illumination is uniform.

A Leica 35-mm. type camera with a 50-mm. Sumar lens was used.

Photographs were taken on Eastman Lino-graph ortho film with an exposure time of 7½ sec., at *f* 6.3. An ultraviolet filter and a Pan-Ortho No. 2 filter were used together.

The film was developed 4 min. at 68–70 F. in G. E. X-ray developer.

3 by 3-in. prints were made on defender No. 4 paper exposed for 5 sec. at *f* 4.5, and developed 1½ min. at 70 F.

This method was studied at length to determine whether various amounts of deposits on the glass plate could be distinguished by this photographic technique. Solutions of varying compositions, 0.1 to 1 part of lubricating oil to 99 parts of solvent were prepared. Chemically cleaned instrument glass plates were dipped into the solutions and allowed to air dry. After drying, the plates were dusted and photographed as described above. Results are given in Fig. 4. It will be noted that a good comparison is indicated and that the powder retention varies proportionately with the amount of residual oil.

TABLE I.—RESULTS OF FOGGING TESTS ON SEVEN GROUPS OF ORGANIC MATERIALS.[a]

Sample Description	Loss in Weight, per cent	Surface Condition of Glass Plates
Oil Lubricants		
Instrument oil, from company *A*	0.46	Light fog, finely dispersed
Synthetic lubricating oil, from company *B*	0.23	Very light, finely dispersed fog
Synthetic low volatility aircraft instrument oil, from company *C*	0.28	Light fog
Rotor bearing oil, from company *A*	0.72	Heavy fog, clear oil film
Grease Lubricants		
Synthetic lubricating grease with rust inhibitor, from company *A*	0.98	Slight fog, finely dispersed
Low-viscosity silicone grease, from company *D*	1.16	Slight fog, finely dispersed
High-viscosity silicone grease, from company *D*	0.66	Slight fog, finely dispersed
Anti-Seize Compounds		
Compound composed of 50 per cent zinc dust and 50 per cent grease by weight, from company *A*	0.28	Slight fog
Thread lubricant composed of 50 per cent zinc dust and 50 per cent petrolatum by weight, from company *E*	0.09	Very slight fog
Compound composed of 50 per cent zinc dust and 50 per cent medium viscosity silicone by weight, from company *D*	0.47	Slight fog
Flexible Insulating Tubing		
General purpose clear vinyl tubing, from company *F*	0.90	Heavy fog, oil-like material
Varnished cambric tubing, from company *G*	2.21	Very heavy fog
Polyester resin, saturated Fiberglas tubing, grade A, from company *H*	0.13	Heavy, finely dispersed fog [see Fig. 5 (*upper left*)]
Polyester resin saturated Fiberglas tubing, grade B, from company *H*	0.15	Heavy, finely dispersed fog [see Fig. 5 (*upper right*)]
Silicone saturated Fiberglas sleeving, from company *I*	0.11	Light, finely dispersed fog [see Fig. 5 (*lower left*)]
Wire Insulation		
Vinyl insulated wire, from company *J*	0.099	Light fog
Vinyl insulated wire, from company *K*	0.26	Heavy fog
Impregnating Varnishes		
Field coils impregnated with varnish, from company *L*	0.065	Very slight fog
Field coils impregnated with varnish, from company *M*	0.56	Very slight fog
Rubber		
Buna-N synthetic rubber sheet, medium hardness, from company *N*	0.40	Light fog, oil-like material
Buna-N synthetic rubber sheet, soft, from company *N*	0.88	Light fog, finely dispersed
Neoprene sponge rubber, soft, from company *O*	1.20	Heavy fog
Neoprene sponge rubber, soft, from company *P*	2.30	Heavy fog

[a] Weighed samples were maintained at 82 ± 0.5 C. (180 ± 0.9 F.) for 16 hr., after which vapor deposits were photographed and the samples reweighed to calculate percentage loss in weight and to derive fogging properties.

Results and Discussion

The Materials Laboratory has tested a considerable number of organic materials during the past two years for fogging properties and the results are given in Table I. The materials are listed under seven groups: namely, oils, greases, anti-seize compounds, flexible insulating tubing, wire insulation, impregnating varnishes, and rubber. In all cases the percentage loss in weight and a visual observation of the amount of fog on the glass plates are reported. A typical series of photographs of fog deposits obtained from some flexible insulating tubing samples appear under Fig. 5 and are illustrative of the type of photographs obtained for record purposes.

The magnitude of the fog deposits is generally proportional to the percentage loss in weight of the samples tested.

However, in several cases this is not true, particularly if one compares one group of materials with another. A possible explanation may be that some organic materials give off vapors during the heating period which are of the high-vapor pressure, low-boiling-point type which do not readily condense on the cooled glass plates. On the other hand, there are some materials which liberate low vapor pressure vapors which readily condense on the glass plates and therefore exhibit a heavy fog for the same loss in weight. The amount of these breakdown products varies with the type of organic materials tested and is difficult to predict. This test method, however, has been found very valuable in determining fogging properties of materials of the same type since both a loss in weight of the sample and the visual effects of the condensed volatile materials are obtained. These results will determine whether a material can be used at high ambient temperatures in the vicinity of optical systems, electrical contacts, or in evacuated systems.

Conclusions

Organic materials such as lubricating oils, greases, wire insulation, rubber, etc., which are used in equipment operated at high ambient temperatures form vapors which may condense to produce fogging problems.

A test method has been developed for evaluating and recording the fogging properties of organic materials on a comparative basis to determine whether they will be suitable for use at ambient temperatures of approximately 82 C. (180 F.).

It is possible by means of this test procedure to select materials having low fogging characteristics for use in equipment where fogging is a problem.

Acknowledgment:

The authors wish to thank Mr. G. Gadke for designing the cells and Miss J. LaVine and Mr. C. Abeles for performing the laboratory tests.

The Determination of Freezing Point of Engine Antifreeze*

By R. E. Mallonee[1] and F. L. Howard[2]

Synopsis

The development by Subcommittee I of ASTM Committee D-15 on Engine Antifreezes of a simple apparatus and technique for determining the freezing point of aqueous solutions of engine antifreeze is described. The method represents a combination of the best features of three suggested procedures with other modifications suggested from experience gained in an extensive cooperative testing program. Data are presented indicating the accuracy of the determination along with observations by the cooperating laboratories on the limitations of the apparatus. Since the final test program is not complete, the material presented is for information only, but should be of help to laboratories desirous of setting up the apparatus.

At the time Committee D-15 on Engine Antifreezes was founded, in 1947, it was recognized that one of the first problems to be considered was the development of a standard method for the measurement of freezing point of aqueous antifreeze solutions. Subcommittee I on Freezing Point Determinations was therefore organized with Donald B. Brooks of the National Bureau of Standards as Chairman. Mr. Brooks continued in this capacity during the study and testing of several methods and the initial development of the present test. In 1949, Mr. Brooks resigned from the chairmanship because of a change in employment and was replaced by R. E. Mallonee of the National Carbon Research Laboratories.

Initially, the subcommittee considered two methods for possible development and comparison tests. One of these was to be a routine method, employing a relatively simple apparatus and technique, so that an average laboratory would experience no difficulty in carrying it out. The other, a more precise method, was to be studied as a means of establishing basic values. This account deals with the development of the first of these methods.

Since the testing of the freezing point method is not completed, the material presented in this paper is published as information only. The data obtained to date, however, show it to be quite reproducible and suitable for the determination of the freezing point of engine antifreeze. Any changes which may be made after assembly of all the data and comments from participating laboratories will undoubtedly be minor in nature.

Discussion

Early in 1948, it was agreed that a cooperative test program would be carried out on three methods used by three of the committee members. Results from this test program were to be used in evaluating the methods. The bases of the methods were essentially similar: the sample contained in a cylindrical tube is stirred and gradually cooled by a refrigerant until crystallization takes place. The methods differ, however, in the interpretation of "freezing point," manner of cooling, and temperature measurement. The salient features of each method are:

Method A.—The sample is contained in a double-walled tube, and the rate of cooling depends on the degree of vacuum in the annular space. This can be varied by operation of a vacuum pump connected to this annular space. The sample is stirred by a reciprocating helical stirrer. The sample tube is supported in a cylindrical Dewar flask over liquid nitrogen. Vapors from the nitrogen bathe the sample tube and provide means of lowering the sample temperature. Temperature is measured by a copper-constantan thermocouple in the sample, connected to a Leeds & Northrup 8662 potentiometer. The freezing point is taken as the temperature at which crystals are first visible.

Method B.—The sample is contained in a double-walled, partially evacuated tube, supported in a bath of alcohol or other liquid. Cooling is accomplished by adding dry ice to the bath. A reciprocating helical stirrer is used. Temperature is measured by means of a special thermometer graduated from −38 to +33 F. The "freezing point"

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to ASTM Headquarters, 1916 Race St., Philadelphia 3, Pa.

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[1] National Carbon Research Laboratories, Cleveland, Ohio.

[2] National Bureau of Standards, Washington, D. C.

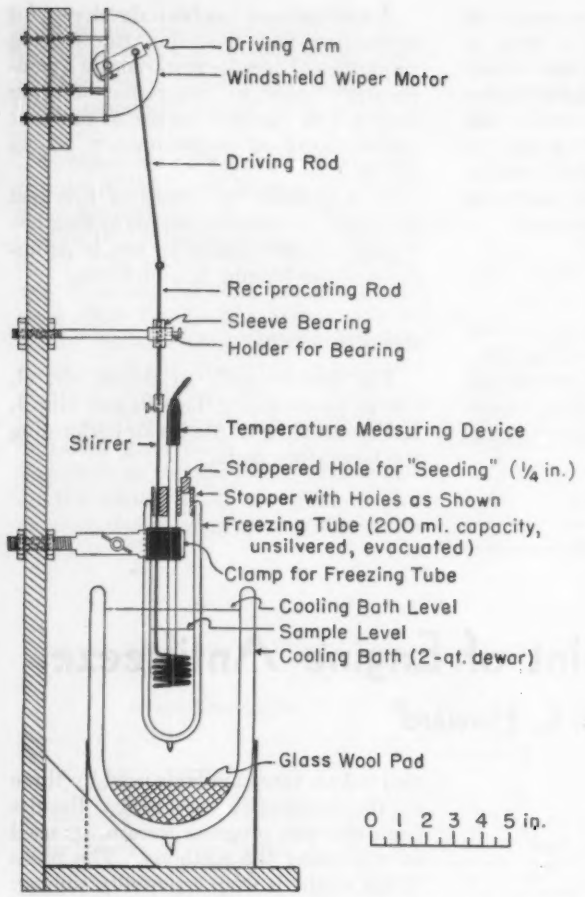

Fig. 1.—Assembly of Freezing Point Apparatus.

is the highest temperature attained after undercooling.

Method C.—This laboratory had no routine method for freezing point determinations, but submitted a modification of its more precise method for determining the freezing points of hydrocarbons. In this modification, the sample tube, a large test tube, is located within an evacuated flask, supported in a bath of dry ice-carbon tetrachloride-chloroform mixture. A helical stirrer driven by a windshield wiper motor is used. Temperature is measured periodically by a Weston dial thermometer, and a plot of time *versus* temperature is made. The freezing point is the temperature at which the cooling curve intersects the extrapolated freezing curve.

Test Program

Producer members agreed to furnish test samples to each of the cooperating laboratories, and a test program was circulated by Chairman Brooks. Laboratories participating in the program were: Enjay Co., Ford Motor Co., Kimble Glass Co., The Texas Company, U. S. Industrial Chemicals, Inc., National Carbon Division of Union Carbide and Carbon Corp., and the National Bureau of Standards. Samples of alcohol and glycol antifreezes were contributed by the Enjay Co., U. S. Industrial Chemicals, Inc., Carbide and Carbon Chemicals Division of Union Carbide and Carbon Corp., National Carbon Division of Union Carbide and Carbon Corp., and E. I. du Pont de Nemours and Co. The test program required measurements of freezing points on 30, 50, and 60 per cent solutions of ethylene glycol, propylene glycol, three commercial glycol antifreezes, and five commercial alcohol antifreezes.

Shortly after the test program was initiated, one of the laboratories pointed out that no specific recommendations had been provided for mixing the antifreeze and water, and that considerable error could be introduced if the solutions were not compounded by a uniform procedure. Accordingly a mixing procedure was adopted and circulated to the various participants. In this formula, the concentration of an antifreeze in aqueous solution is expressed as the ratio of the initial volume of the antifreeze to the final volume of antifreeze and water, both initial and final volumes being measured at 20 C. (68 F.).

By early Fall of 1948, the test results were reported to Chairman Brooks, who analyzed the data. It was found that many laboratories had departed from the suggested procedure. One company, for example, ran the test by their own method, which was not one of the three selected for evaluation. Another failed to follow the mixing directions provided. After the results of one laboratory had been reported, it was found that the thermometer used was in error by about 2 F. Several minor changes were made in the procedures, particularly regarding temperature measurement, cooling baths, and stirring. For instance, one laboratory liked the windshield wiper motor stirring arrangement so well that they used it on all tests. The same laboratory used copper-constantan thermocouples and Leeds & Northrup 8662 potentiometer for all tests because the Weston thermometer (*Method C*) was found to be unsuitable, and the special thermometer for *Method B* was not received in time to take measurements. After a few preliminary runs in this laboratory, it was found that dry ice was not an effective refrigerant for the higher concentrations of antifreeze, so liquid nitrogen was used in all the tests.

The observations and criticisms of the individual laboratories brought out the following points regarding each method:

Method A.—Most of the observers reported difficulty in seeing the first crystals form, particularly in cloudy or opaque antifreeze solutions. Since the sample tube is not kept evacuated, moisture from the air caused frosting of the inner surfaces. It was suggested that a drying tube be used on the outlet of this tube. Although liquid nitrogen is not generally available, this method was found to be the fastest.

Method B.—The specified thermometer was not suitable for measuring the lowest temperatures encountered. Dry ice was not effective in cooling the high concentration antifreezes. Many of the samples did not undercool.

Method C.—Of the three methods, *Method C* was found to be the slowest. Several participants experienced difficulty in obtaining "clean breaks" between the cooling and freezing curves, particularly with the higher glycol concentrations.

The standard deviations were calculated for all the data, and it was found that the precision of all three methods deteriorates at low temperatures. *Method C* data showed the largest deviations. Brooks therefore recommended that no further tests be made on this method without modifications. *Method A* was found to be the most reproducible.

Based on this statistical analysis and recommendations of the participating laboratories, a draft of a method for freezing point determinations incorporating the best features of the three methods studied was circulated to the committee. At a meeting of Subcommittee I held in February, 1949, this draft was considered by the members and referred to a study group headed by B. E. Tiffany of Ford Motor Co. with E. B. Snyder of Kimble Glass Co. and R. E. Streets of the National Bureau of Standards. The discussions had indicated the desirability of a simple method, using standard and readily available items wherever possible. After careful study, a tentative method was written which was approved by the committee members and recommended for test. The essential features of the method, described in more detail in the Appendix, are:

(1) The freezing point is defined as the temperature at which crystallization begins in the absence of undercooling, or

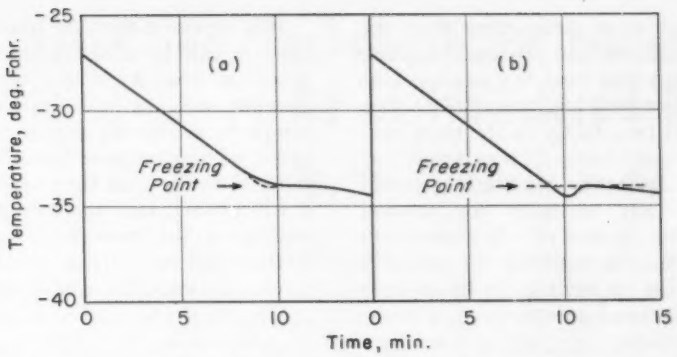

Fig. 2.—Time-Temperature Cooling Curves for Determining the Freezing Point of an Engine Antifreeze.

the maximum temperature reached immediately after initial crystal formation in the case of undercooling. The method involves the determination of the horizontal flattened portion of the freezing curve.

(2) The freezing apparatus, as shown assembled in Fig. 1, consists of an evacuated Dewar flask for cooling bath, a 200-ml. evacuated Dewar flask for the freezing tube, a stirring mechanism, suitable clamps and holders for the parts, and temperature-measuring equipment.

(3) A 75 to 100-ml. sample is placed in the sample tube and allowed to cool with stirring. The time-temperature curve at the freezing point is plotted on rectangular-coordinate paper and the freezing point determined as shown in Fig. 2. Where the curve shows a definite flat or plateau during freezing, the freezing point is taken as the intersections of the cooling curve and the freezing curve. If undercooling is present, the freezing point is the maximum temperature reached immediately after undercooling.

A modification of the sample tube to include a seeding tip, as shown in Fig. 3, had been suggested by the du Pont laboratory and some data on freezing point determinations using the tube were submitted by them to show its value in eliminating undercooling. The committee members felt that the tube was undoubtedly an improvement but that it should be submitted to cooperative tests before being accepted. A short test program to verify the reproducibility of the determination and the desirability of adopting the seeding tube was proposed using two aqueous solutions each of ethylene glycol, a commercial two-phase ethylene glycol antifreeze, and a commercial methanol antifreeze. These solutions covered a range of freezing points from about 10 F. to about −55 F. and were made up and distributed by the National Carbon Research Laboratories. Each solution was made up as a single batch and stirred for one half hour before being transferred for shipment in glass containers. The freezing points of the solutions were unknown to the cooperating laboratories, and results were to be obtained from all laboratories before release. It was decided that each laboratory was to run freezing points by the approved method as well as by the method using the tube with the seeding tip. Since each laboratory was working on the same solutions and errors involved in mixing were eliminated, it was felt that the results would give a good indication of the method's reproducibility.

Results as shown in Table I of data available by May 22, 1950, show good reproducibility and indicate the procedure using the sample tube with the seeding tip to be comparable to that using the evacuated tube and manual seeding of the solutions at the freezing point. Since nine laboratories are involved in these tests, it is planned to obtain results from at least two more before making the final analysis and recommendations.

Although these data were not discussed at the February, 1950, meeting, several criticisms of the method and suggested improvements were offered. It was universally agreed that the fully evacuated tubes unduly extended the time required for the determination, particularly for the lower freezing points. One of the laboratories had obtained poorly evacuated seeding-tip tubes which gave good results with a much faster cooling rate. They had also worked with completely unevacuated tubes with satisfactory results, the cooling rate with the presently selected tube dimensions being about right for the range of freezing points studied. It was suggested that those laboratories who had not as yet obtained seeding-tip

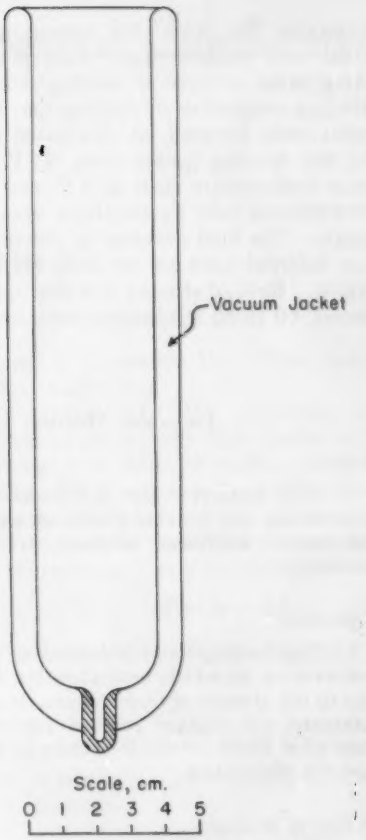

Fig. 3.—Freezing Point Tube with Seeding Tip.

This tube may be purchased from either Labglass, Millville, N. J., or Corning Glass Works, Corning, N. Y.

TABLE I.—COOPERATIVE TEST RESULTS ON ANTIFREEZE SOLUTIONS.

Solution[a]	Laboratory A		Laboratory B	Laboratory C		Laboratory D	Average, deg. Fahr.
	Operation No. 1, deg. Fahr.	Operation No. 2, deg. Fahr.	Operation No. 1, deg. Fahr.	Operation No. 1, deg. Fahr.	Operation No. 2, deg. Fahr	Operation No. 1, deg.. Fahr.	
Sample Tube Without Seeding Tip							
C-5-2 No. 1.....	7.3	6.0	6.3	6.5	6.4	7.3	6.6
C-5-2 No. 2.....	−44.0	−44.3	−43.8	−44.0	−44.6	−43.6	−44.1
C-2-2 No. 1.....	− 1.5	− 1.6	− 1.8	− 1.3	− 1.5	− 0.8	− 1.5
C-2-2 No. 2.....	−36.1	−36.5	−36.8	−37.4	−37.7	−35.9	−36.7
C-1-1 No. 1.....	9.1	8.6	8.6	8.5	9.0	9.3	8.9
C-1-1 No. 2.....	−55.7	−56.4	−55.7	−55.5	−55.0	−56.2	−55.8
Sample Tube with Seeding Tip							
C-5-2 No. 1.....	7.4	5.8	6.3	6.4	6.6	7.0	6.6
C-5-2 No. 2.....	−43.2	−44.2	−43.9	−44.2	−43.8	−44.1	−43.9
C-2-2 No. 1.....	− 1.5	− 1.5	− 2.0	− 1.7	− 1.9	− 1.2	− 1.6
C-2-2 No. 2.....	−34.6	..	−36.7	−37.8	−37.1	−36.4	−36.5
C-1-1 No. 1.....	9.7	9.6	8.4	9.0	8.8	9.3	9.0
C-1-1 No. 2.....	−54.0	..	−56.0	−56.6	−55.2	−56.3	−55.6

[a] Committee D-15 code designations are used for antifreeze materials.

tubes for the work try unevacuated tubes and include their observations along with a typical cooling curve. Another suggestion offered was that two tubes could be used, an evacuated one for the freezing points from 32 F. to some temperature such as 0 F. and an unevacuated tube for the lower freezing points. The final decision on this point was deferred until all the data are obtained. Rate of stirring was also questioned, 60 to 80 strokes per min. being considered more satisfactory than the specified 125 to 150 strokes. Another observation was that the seeding tube was not a cure-all and that undercooling would still be a factor in the more concentrated solutions. It was hoped that the tube with the seeding tip would eliminate any necessity for manual seeding, but in view of this observation it was thought desirable to retain a specification on seeding for those cases where it is found necessary.

It is expected that the freezing point method will be adopted essentially as given in the Appendix with minor changes such as specification of the sample tube with the seeding tip and the extent of evacuation of the tube. From the data available at the time of writing, it will be seen that the test program is confirming the reproducibility of the method and indicates a favorable comparison between the sample tubes.

APPENDIX

Proposed Method of Test for Freezing Points of Aqueous Engine Antifreeze Solutions

Scope:

1. This method of test is intended for determining the freezing points of aqueous engine antifreeze solutions in the laboratory.

Definition:

2. The *freezing point* is defined as the temperature at which crystallization begins in the absence of undercooling, or the maximum temperature reached immediately after initial crystal formation in the case of undercooling.

Outline of Method:

3. This method involves the determination of the time-temperature curve prior to freezing and the determination of the horizontal or flattened portion of the freezing curve. The freezing point is taken as the intersection of projections of the cooling curve and the freezing curve

If the solution undercools, the freeeing point is the maximum temperature reached after undercooling.

Apparatus:

4. The freezing point apparatus, shown in Fig. 1, consists of a Dewar flask for the cooling bath, a smaller Dewar flask for the freezing tube, a stirring mechanism, suitable clamps and holders for the parts, and temperature measuring equipment.

(*a*) *Cooling bath*, in which the refrigerant is contained, is a standard 2-qt. Dewar flask. The flask may be silvered or unsilvered, and is supported in a close-fitting container. A pad of glass wool is placed in the bottom of the flask to protect it from damage by the tip of the freezing tube.

(*b*) *Freezing tube* consists of a 200-ml. evacuated, unsilvered Dewar flask.[3] The tube is closed by a cork having a central hole for the thermometer or thermocouple, a second hole placed to one side for passage of the stirring rod, and a third hole for introducing the wire for seeding at the appropriate time.

(*c*) *Stirring mechanism* consists of a five-coil stirrer formed of stainless steel wire $\frac{1}{16}$ in. in diameter. The coils are so spaced that, in the extreme upward position during operation, no coils are exposed above the surface of the sample. The stirrer is agitated by means of an ordinary windshield wiper motor operating through suitable linkages so as to provide linear motion of the stirrer. The length of the stroke is adjusted so that the coil just clears the bottom of the freezing point tube at the low point of the stroke.

(*d*) *Temperature Measurement.*—A resistance thermometer or a multijunction copper-constantan thermocouple may by used with suitable measuring instruments, providing these give an over-all sensitivity of 0.2 F. (0.1 C). The instrument should be calibrated before each series of determinations by using suitable reference standards.

Note 1.—Liquid-in-glass thermometers may be used when less accuracy is acceptable, provided reference standards are used for calibration purposes.

Refrigerant:

5. *Refrigerant*, solid carbon dioxide in alcohol or other suitable bath liquid.

Note 2.—A layer of dry ice at least 0.5 in. in thickness must be maintained in the bottom or on the top of the cooling bath during a determination, depending on the bath liquid used. Adequate precautions should be taken against fire hazards or toxic effects of bath liquids, or both.

Note 3.—When the freezing point of the antifreeze solution is −50 F. or below, liquid nitrogen should be used.

Procedure:

6. (*a*) Assemble the apparatus as shown in Fig. 1 with no refrigerant and no sample of antifreeze yet in place. Check the operation of the stirring mechanism after assembly to be sure that all parts operate freely.

(*b*) Fill the Dewar flask surrounding the freezing tube with the refrigerant liquid, adding pieces of solid carbon dioxide from time to time to maintain the conditions mentioned in Note 2. Temporarily remove the stopper from the freezing tube and introduce 75 to 100 ml. of the sample.

Note 4.—The sample is to be prepared as directed in the Proposed Method of Sampling Engine Antifreezes.[4] The secondary phases need not be separated.

Note 5.—The sample may be precooled to approximately 15 F. above the expected freezing point before introducing it into the freezing tube.

(*c*) Start the stirrer and adjust it to operate at 60 to 80 strokes per minute. As soon as stirring is begun, observe and record the temperature of the sample at regular intervals of time (Note 6). As the expected freezing point is approached, the time intervals should be quite short, 15 sec. if possible. At the expected freezing point, seeding should be started to prevent undercooling. This can be accomplished by introducing a wire which has a small piece of ice frozen on its tip or simply by dropping a small piece of ice directly into the solution. In either case, the ice should be cooled considerably under the freezing point of water to keep it as dry as possible to avoid diluting the solution.

Note 6.—Cooling rate must be less than 2 F. per min. If the rate is greater when using regular refrigerant liquid, the Dewar flask is probably defective.

(*d*) Continue the temperature readings at regular intervals for at least 10 min. after the apparent freezing point.

Report:

7. Plot the observed temperature against time on rectangular coordinate paper. Where the curve shows a definite flat or plateau during freezing, the freezing point is taken as the intersection of projections of the cooling curve and the freezing curve. See Fig. 2. If the solution undercools, the freezing point is the maximum temperature reached immediately after undercooling.

Note 7.—The amount of undercooling should be held to a minimum. If the undercooling exceeds 2 F., the test should be rejected.

Precision:

Note 8.—The precision of the freezing point determination will be determined on completion of the cooperative test program.

[3] A Dewar flask (Corning Catalog No. 4540 Corning Glass Works) which has been evacuated with Cenco Hy-Vac Pump or equivalent, and sealed, is satisfactory.

[4] This method is in preparation by Committee D-15.

Apparatus and Technique for Measuring Thermal Conductivity of Powdered Material

By W. Z. Girton[1] and J. H. Potter[2]

SYNOPSIS

This paper reports work on development of apparatus and technique for measuring thermal conductivity of powdered material. Design and operation of the test cell was done in the mechanical engineering laboratories of Johns Hopkins University.

Dry, powdered material was placed in the annular space between two concentric cylinders. The flow of heat was radially outward, and the quantity of heat was measured by the temperature rise of the cooling water surrounding the outer cylinder. Guard rings were used to minimize end effects.

The powdered material was examined for dryness, particle size, and apparent density. The powder was compacted in the test annulus by impressing a vibration of known amplitude and frequency upon the test cell for a specified time.

Tests were made with samples of powdered zinc, carbonyl iron, copper-copper oxide eutectic, and calcium carbonate. Four runs were made with each type of powder to establish the reproducibility of the method.

THE importance of the thermal properties of materials is attested in the voluminous literature on that subject; however, the preponderance of the information available is concerned with substances in the solid, liquid, or gaseous states. The present widespread use of powdered materials in industry has caused a demand for data on the thermal properties of powders. This is especially true in the plastics and food industries.

In this paper, the design and operation of a steady state apparatus for determining the thermal conductivity of powdered material is reported. The principal variables in the study were considered to be:

1. temperature level,
2. chemical homogeneity of the powder,
3. mechanical homogeneity or particle size,
4. apparent density related to the packing tendency of the material,
5. chemical and physical stability of the powder at test temperatures, and
6. moisture content of the powder sample.

The test method consisted of heat-flow and temperature measurements on powder samples which had been compacted in the annular space between two concentric cylinders. Uniformity of the source temperature was achieved by using condensing steam at atmospheric pressure. Guard rings were used at each end of the test section to minimize longitudinal heat flow.

THEORY

The principal quantities used in this paper have the following definitions and units:

A = area measured at right angles to the direction of heat flow, square feet. A_m is the logarithmic mean area,
h = enthalpy, Btu. per lb.,
K = thermal conductivity, Btu.-ft. per hr. per sq. ft. per deg. Fahr. K_m is the mean thermal conductivity,
L = length, effective, of test section, ft. (L = 0.177 ft.),
Q = heat flux, Btu. per hr., corrected,
r = radial distance, ft. r_1 and r_2 are the thermocouple radii (r_1 = 0.625 in., r_2 = 1.250 in.),
t = temperature, deg. Fahr, and
w = water flow rate, g. per min.

Under steady state conditions the radial flow of heat by conduction between concentric cylinders may be represented by the fundamental Fourier equation:

$$Q = -K_m A_m \frac{dt}{dr}$$

where:

$$A_m = \frac{A_2 - A_1}{2.3 \log (A_2/A_1)}$$

$$= \frac{2\pi L(r_2 - r_1)}{2.3 \log (r_2/r_1)}$$

the heat flow equation may then be expressed as:

$$Q = \frac{K_m 2\pi L \Delta t}{2.3 \log (r_2/r_1)} \quad \ldots\ldots(1)$$

where Δt represents the actual radial temperature drop.

Nukiyama (1, 2),[3] reporting on thermal conductivity tests made with cylinder-type cells, presented a modification of this equation in which end effects were included.

If the rate of heat flow is measured by the enthalpy rise of the cooling water:

$$Q = 0.1323w(h_2 - h_1) \quad \ldots\ldots(2)$$

Combining equations and solving for the thermal conductivity:

$$K_m = \frac{0.1323w(h_2 - h_1)}{[2\pi L \Delta t/2.3 \log (r_2/r_1)]}$$

For the particular dimensions used in the test apparatus:

$$K_m = \frac{0.0824w(h_2 - h_1)}{\Delta t} \quad \ldots\ldots(3)$$

APPARATUS

A partially sectioned view of the apparatus is shown in Fig. 1. The heat source is the central tube marked (*4*). A fully submerged 300-watt electric heater (*12*) generated steam which was condensed in the long test section above it. A vent (*21*) limited the steam pressure to 1 atmos. To prevent steam from escaping from the unit, a double pipe condenser (*1*) was used. A drip return rod (*5*) projected downward from the double pipe condenser so that subcooled condensate could be returned to the heater without flowing over the walls of the test section. The copper test section was 6 in. long with an outside diameter of 1 in.

The powder under test was held between the heater tube (*4*) and the sink jackets (*8*), (*10*), (*8*). It filled the space between the two transite plates (*6*), (*6*). The test thermocouples are shown in the powder at (*23*). There were six pairs of thermocouples; three pairs were located on each spider (*9*), 120 deg. apart.

Asbestos insulating tape was used on the boiler unit and on the reflux condenser. A thermocouple attached to the outside of the boiler tube, under the insulation, showed that the tube temperature did not exceed the temperature of

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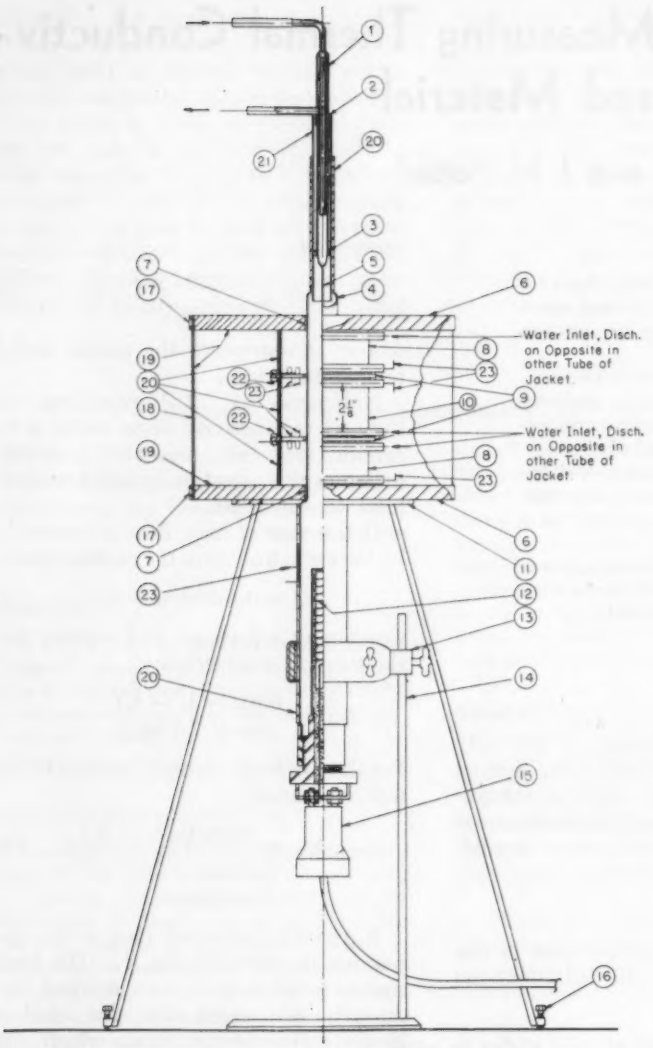
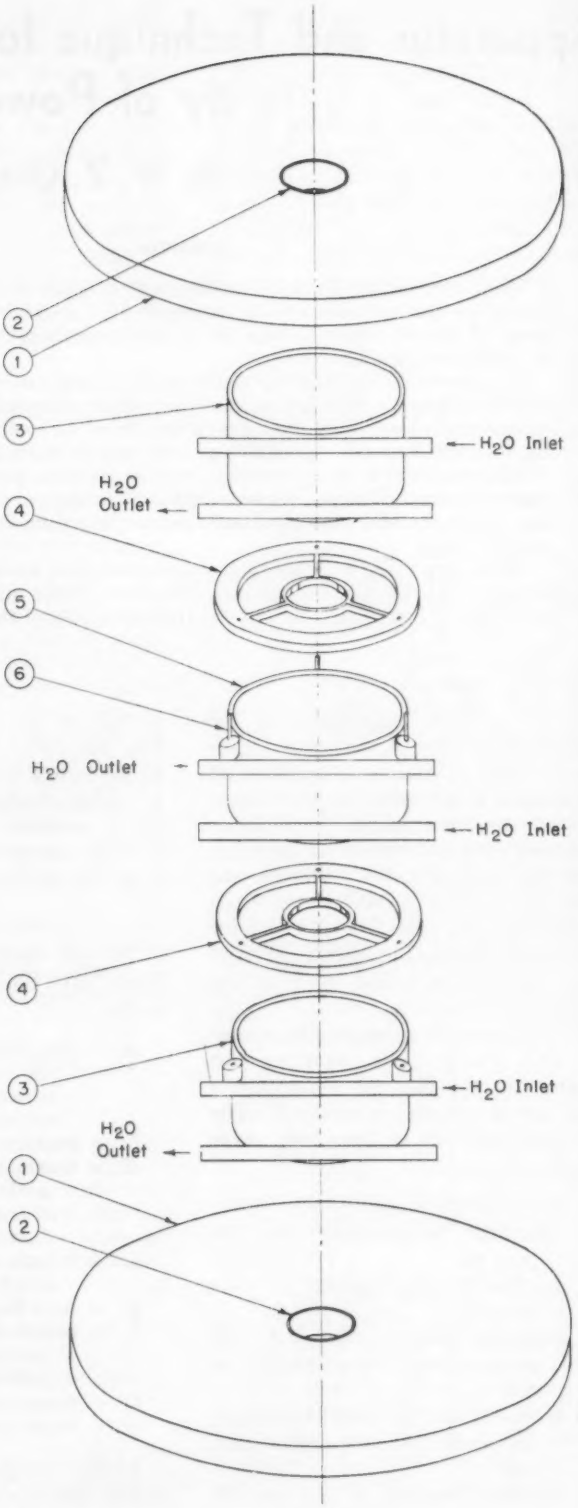
[3] The boldface numbers in parentheses refer to list of references appended to this paper.



1	Condenser	12	Heater Assembly
2	Cork Ring	13	Clamp
3	Cork Spacer	14	Stand
4	Steam Tube	15	Heater Plug
5	Drip Return Rod	16	Leveling Screws
6	Transite Base and Top Disk	17	Clamp Rings
7	Copper Bushing	18	Asbestos Paper, 1/16 in. Thick
8	Water Jacket Guard Ring	19	Aluminum Radiation Shielding
9	Locating Spider	20	Asbestos Insulating Tape
10	Water Jacket Specimen Container	21	Vent
11	Support Stand	22	Locating Pins
		23	Thermocouples

Fig. 1.—Apparatus for Measuring Thermal Conductivity of Powdered Materials.



1	Transite Base and Top Disk	4	Locating Spider
2	Copper Bushing	5	Water Jacketed Specimen Container
3	Water Jacketed Guard Ring	6	Locating Pins

Fig. 2.—Exploded View of Sink Arrangement.

the boiling water, indicating that there was no longitudinal heat leakage into the test section.

Aluminum foil was used between the transite cover plates and the heat sinks (*19*), and also on the extreme outer wall (*19*). A sheet of asbestos paper (*18*) held by clamp rings (*17*) completed the outer wall.

The sink arrangement is shown in exploded view in Fig. 2. The central test cell (*5*), 2 in. long,[4] was bounded by two transite spiders, flanked in turn by two guard rings each of which was $1\frac{1}{2}$ in. long. Note that the water was supplied to the sink sections tangentially through copper tubes attached to the shells. The water temperature thermocouples were inserted in these copper tubes, in opposition to the direction of water flow.

One of the guard ring sections is shown in Fig. 3. All of the sink sections were made from pieces of 3-in. brass tubing $\frac{1}{16}$ in. thick. One piece of tubing was turned externally so as to leave a narrow band at each end with a thickness of $\frac{3}{64}$ in. The main body was then turned so as to leave a wall of $\frac{1}{64}$ in. A

[4] The "effective" length, L, used was the cell length plus one-half the thickness of each spider ($L = 2\frac{1}{8}$ in.).

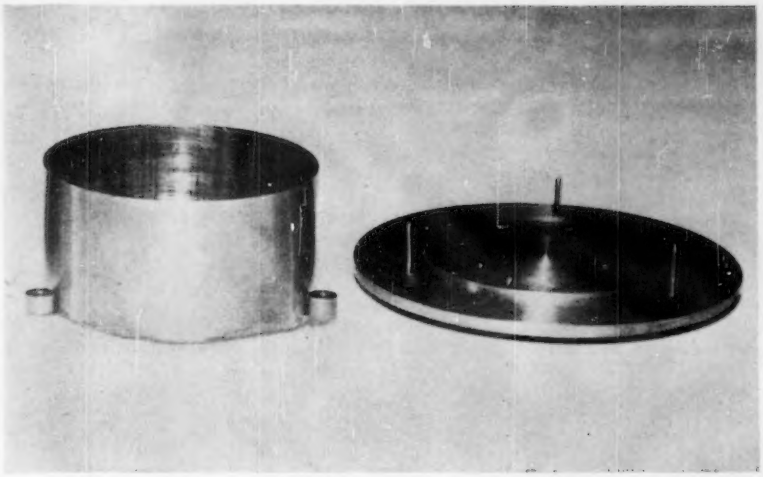


Fig. 3.—Sink Element for Guard Ring with Fixture for Positioning the Alignment Lugs.

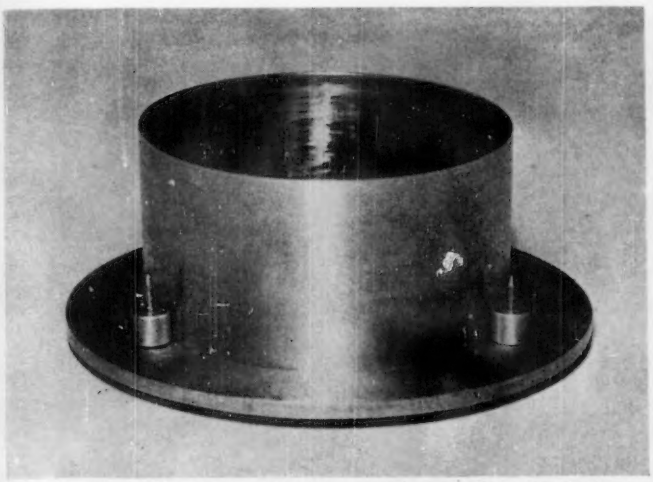


Fig. 4.—Sink Element on Positioning Fixture Prior to Soldering Lugs to the Cylinder.

Fig. 5.—Thermocouple Spider on Drill Jig.

second piece of tubing was turned internally over the full length until only a $\frac{1}{64}$-in. wall was left. The second tube was then slipped over the first and the edges were silver soldered. This left an annular space $\frac{1}{32}$ in. wide for the circulation of the coolant water. The copper tubes for the inlet and outlet water connections were then soldered in place. Just inside these tubes, small baffles were arranged so that coolant water could not short-circuit from inlet to outlet.

Figure 3 shows the positioning fixture with a guard ring cooler element. At the bottom of the latter, small brass lugs have been placed. These lugs were soldered to the cooler when it was in place on the fixture. This made it possible to set the lugs 120 deg. apart, and to insure that succeeding cooler sections could be matched up. Figure 4 shows the cooler on the fixture prior to soldering. Positioning lugs were attached top and bottom to the test section, but on only one end of each of the guard rings. After all of the soldering work was completed, each cooler section was air tested for leaks, then tinned all over. The outside surfaces were then wrapped with asbestos tape.

The thermocouple spiders were made from $\frac{1}{8}$-in. transite sheet. In Fig. 5 an unfinished spider is shown on a special drill jig. The latter served to locate the thermocouple holes with respect to the center of the heat source tube and also to locate the holes for the lug pins properly. Referring to Fig. 2, note that the center hole in the spider was reduced to three lands, 120 deg. apart, and that these lands were not located on the same radii as the spider legs. This was done in an effort to reduce the radial heat loss through the spider legs.

Thermocouples:

The test thermocouples were made from 0.032-in. (outside diameter) copper tubing, each unit being $\frac{7}{8}$ in. long. At the base of the tube, a length of No. 28-gage copper wire was gas welded. An enameled No. 28-gage constantan wire was threaded through the tube and silver soldered at the tip. All thermocouples were calibrated against the boiling points of distilled water and c.p. benzene. A Leeds & Northrup portable precision potentiometer was used in both the calibrations and the tests.

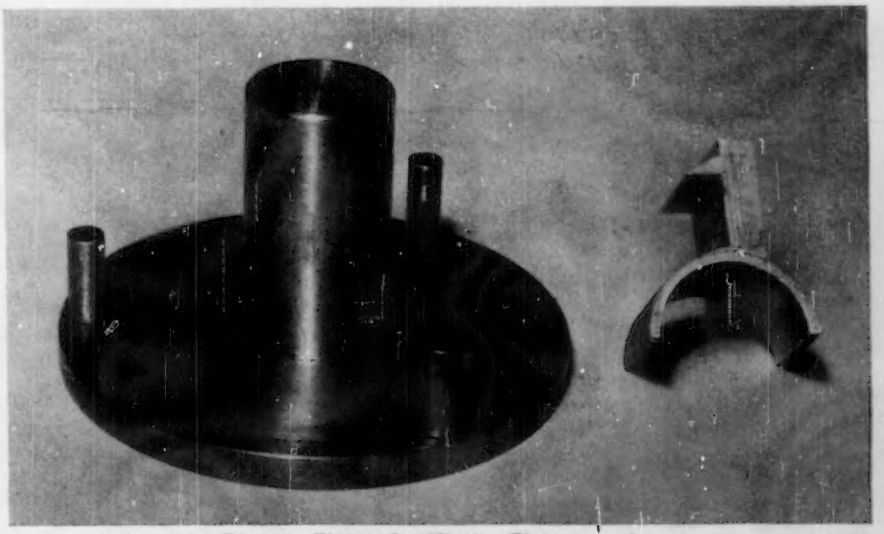


Fig. 6.— Fixture for Aligning Thermocouples.

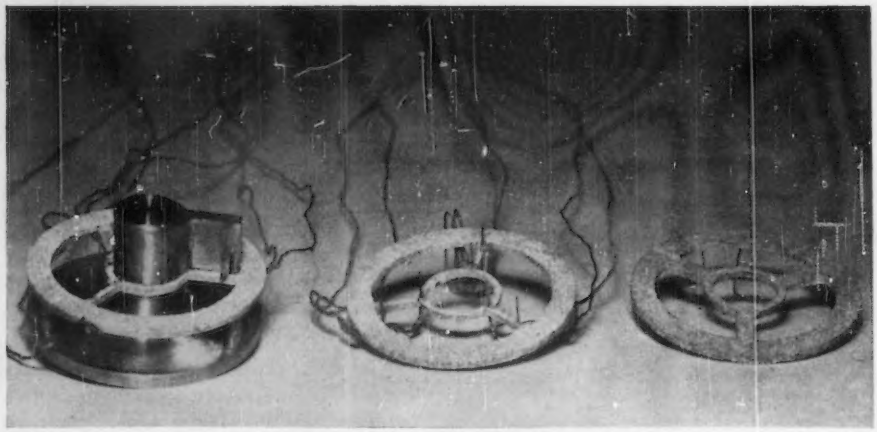


Fig. 7.—Steps in Spider Assembly.

Rough spider (*right*); spider arms filed thin and thermocouples in place (*center*); thermocouples being aligned with special fixture (*left*).

In order to fix the radial positions of the thermocouples, a special device was used. This consisted of a brass cylinder and a steel segment as shown in Fig. 6. The thermocouples were set in the transite spiders so as to project $\frac{1}{2}$ in. from the spider. They were then cemented in place.

The procedure in aligning the thermocouples is indicated in Fig. 7. The rough spider is shown at the right. In the center view, the spider legs have been reduced and the thermocouples located and cemented. In the left view, the whole assembly has been placed on a special alignment fixture, the center of which is a brass cylinder turned to the same diameter as the heater element. A steel segment having a curved base was held snugly against the brass cylinder. Arms on the segment (Fig. 6) established the radial distances of each of the thermocouples from the center line of the brass cylinder, hence from the center line of the heater. In this manner, the thermocouples were located at radii of 0.625 and 1.250 in., respectively.

Test Specimens

Four samples of c.p. powdered materials were used: copper-copper oxide eutectic, carbonyl iron, zinc, and calcium carbonate. Samples of each of these powders were photographed through a geological microscope with a calibrated grid pattern for purposes of comparison. These are shown in Figs. 8 to 11. It is interesting to note that the particles are of nearly spherical form for the three metallic powders. Some notion of particle size may be obtained from comparison with the grid dimensions. An estimate of particle size distribution was made from the photographs and is given in the Appendix. (See Table III).

Each of the powder samples was checked for moisture content by drying in an electric furnace until the sample showed no change in weight. An analytical balance with a sensitivity of 0.1 mg. was used. In order to assure that the sample had had maximum exposure to moisture, these tests were run after the thermal conductivity tests. The dryness tests showed that the samples were essentially free from moisture.

Method of Test

Prior to each test, the water jackets and thermocouples were thoroughly cleaned, and the thermocouples on the spiders were checked for straightness and position. The sinks were then assembled and connected to the coolant water supply tank. The sinks and tubing were purged of air, and the water

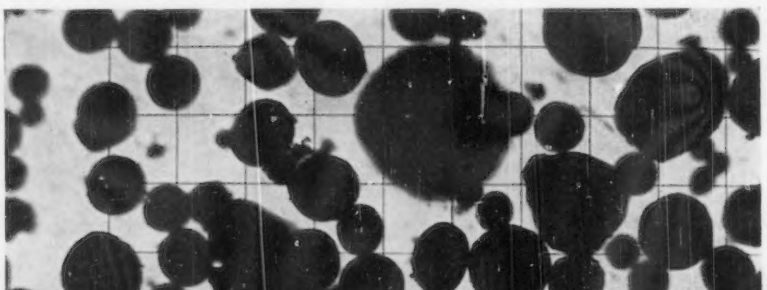


Fig. 8.—Powdered Copper (Width of Large Grid is 67.2 μ).

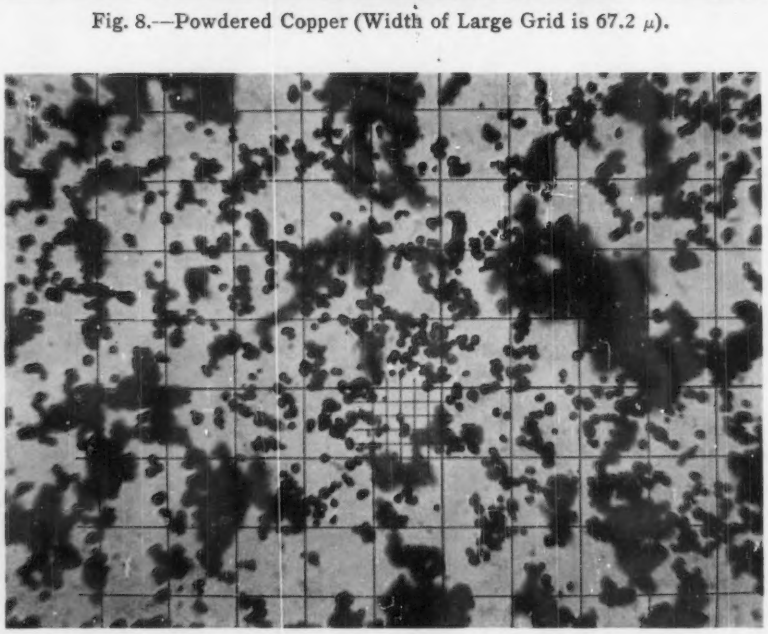


Fig. 9—Carbonyl Iron Powder (Width of Small Grid is 6.6 μ).

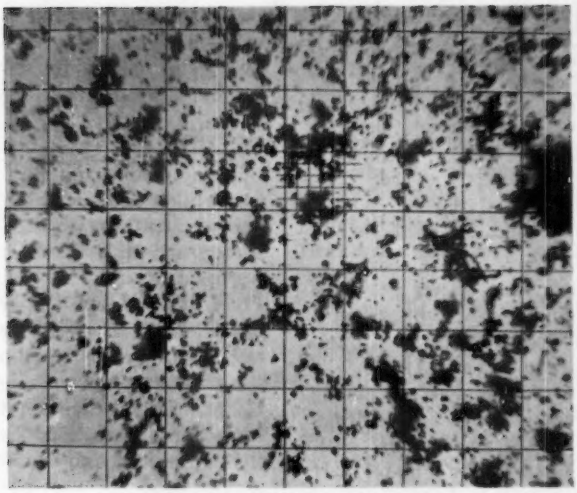


Fig. 10.—Powdered Zinc (Width of Small Grid is 6.6 μ).

flow rates to the various sections were set.

The difficulties encountered when testing powdered materials in a guarded hot plate apparatus have been mentioned by Allcut (3). The ASTM has offered two methods for compacting powders,[5] but has not fully specified the manner in which the shaking or vibrating of the apparatus is to be done. In lorder to establish uniformity in the coading of the test cell, the following procedure was used:

A container of powder was weighed. An electric vibrator attached to the apparatus was started as the pouring of the powder began. The vibrator had a frequency of 122 cycles per sec. and was capable of imposing an acceleration of 70 microinches per sec. per sec. on the empty test cell, 60 when loaded with 1185 g., and 42 when loaded with 2562 g. The powder container was weighed after the test cell had been filled, and the loss in weight of the powder container divided by the volume of the test cell was reported as the apparent density of that particular substance. The vibrator operated for 4 min. The value of this loading method may be judged by the fact that the greatest variation in apparent density in any run was less than 1 per cent.

The top transite cover plate was then put in place and the radiation shielding located. The reflux condenser was connected and the heater was plugged in. All of the thermocouple connections had previously been made.

A period of three or more hours was required before thermal equilibrium was established. Careful adjustment of the water flow to the guard rings was necessary to ensure that temperatures were equal at the line of contact between the central test cell and each guard ring. This precaution was necessary in order to prevent longitudinal heat leakage between the test cell and the guard rings.

The heat flow through the powder was assumed to divide, at each end, between the test section and the guard ring. The effective length of powder, L, included two half thicknesses of the spiders. The coolant water leaving the test-cell sink was collected and weighed over a given time interval. The temperature rise of this water was measured, and the heat flux was determined from the product of the weight of water per unit time and the enthalpy rise (Eq. 2).

Results and Discussion

The mechanism of heat transfer in this series of experiments consisted of a combination of conduction through the particles, convection in the gas pockets surrounding the particles, and radiation between adjacent particles. All of these modes of heat transfer have been combined in a single coefficient which has been designated the "apparent thermal conductivity."

An investigation of the probable radial heat loss along the legs of the thermocouple spiders indicated that while this was small, it was not negligible. Due to the simple configuration of the spider and the fact that steady state conditions prevailed, the correction could be computed from the basic

TABLE I.—EXPERIMENTAL RESULTS.

Powdered Material	Apparent Density	Mean Temperature, deg. Fahr.	Apparent Thermal Conductivity	Variation, per cent
Calcium carbonate	19.8	129.9	0.0437[a]	....
	19.7	129.7	0.0403	+ 1.0
	19.9	130.7	0.0391	− 2.0
	19.9	130.4	0.0402	+ 0.9
Zinc	153.2	136.9	0.252	− 4.9
	152.5	135.7	0.238	−10.2
	153.9	136.1	0.290	+ 9.4
	153.3	136.3	0.279	+ 5.3
Copper-copper oxide eutectic	331.0	147.6	0.509	− 3.6
	332.2	147.9	0.519	− 1.7
	331.8	147.8	0.529	+ 0.2
	331.4	147.5	0.555	+ 5.1
Carbonyl iron	207.3	142.7	0.258	− 2.6
	207.7	142.2	0.252	− 4.9
	207.9	143.4	0.281	+ 6.1
	207.5	142.2	0.268	+ 1.1

[a] Not included in average.

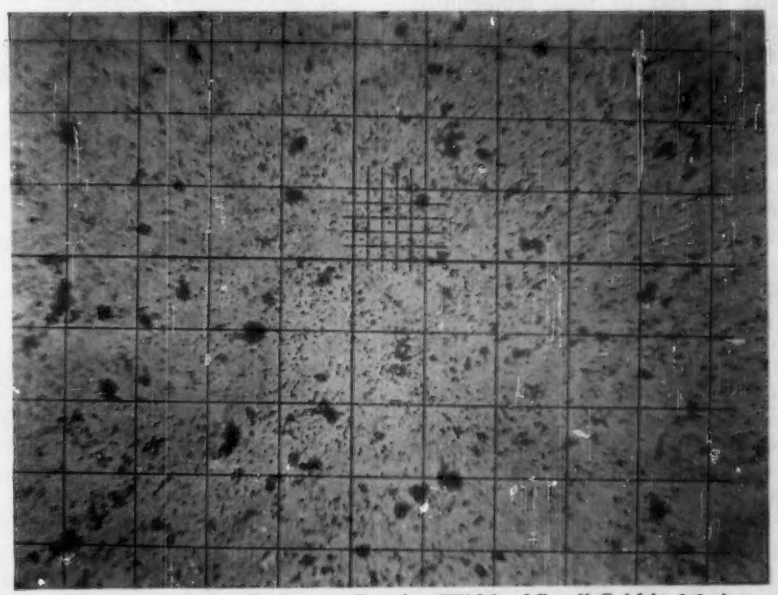


Fig. 11.—Calcium Carbonate Powder (Width of Small Grid is 6.6 μ).

[5] Method of Test for Thermal Conductivity of Materials by Means of the Guarded Hot Plate (C 177 – 45), 1949 Book of ASTM Standards, Part 3, p. 304.

TABLE II.—COMPARISON OF AVERAGE TEMPERATURE DROPS.

Powdered Material	Spider	Average Temperature Drop, deg. Fahr.			
		Run 1	Run 2	Run 3	Run 4
Calcium carbonate	Upper	60.63	61.06	60.80	57.33
	Lower	60.05	60.02	60.48	60.92
Zinc	Upper	64.84	65.84	64.58	64.83
	Lower	64.58	63.69	67.86	61.89
Copper - copper oxide eutectic	Upper	76.51	75.55	73.97	75.31
	Lower	73.64	73.14	73.40	74.53
Carbonyl iron	Upper	70.23	70.23	67.58	65.82
	Lower	69.20	67.28	67.51	70.44

Fourier equation. The value of Q in Eqs. 1 and 2 was corrected for this loss. In general, this loss amounted to less than 1 per cent of the heat flow through the powder, with a maximum correction of 2.19 per cent.

Some test results are reported in Table I. The thermal conductivity is reported in Btu-ft. per hr. per sq. ft. per deg. Fahr. and the variations are shown based on the arithmetic average of four runs.

In general the reproducibility of the results must be considered good. The greatest divergence from the mean value was found in the powdered zinc. Subsequent examination of this sample showed that there had been some "cementing" of the particles, and a photomicrograph suggested the possibility that some sintering had taken place.

In general, the reports of other investigators working with porous or fibrous materials show thermal conductivity values varying in at least as wide a range as those given above. Norton (**4**), investigating thermal conductivity of firebrick, showed that two of three samples agreed within less than 5 per cent, whereas the third differed by about 8 per cent at the upper mean temperature and by 15 per cent at the lower mean temperature. Subsequent work with an improved hot plate still showed variations of 3 to 4 per cent. However, Norton worked in high temperature ranges.

Grundhofer (**5**), testing thermal insulating materials in a guarded hot plate apparatus, showed variations between 9 and 15 per cent.

From cork and lith board tests, A. A. Potter *et al.* (**6**) reported results which varied from the mean by about 4 per cent.

Lander (**7**), using the same sample of mineral fiber in two carefully calibrated hot plates, reported a difference of 4.2 per cent, or a deviation from the mean of 2.1 per cent.

In all of the powders tested, the individual particles were approximately spherical in shape. However, in some cases there was a considerable range of particle sizes in a given test sample. The question arose as to whether the vibrating process had given rise to segregation of the particles and therefore to variation in the measured apparent thermal conductivities between the upper and lower spiders. A comparison of the average temperature drop through the powder is given in Table II.

Table II shows rather close agreement between the average temperature drops on the upper and lower spiders, with neither being consistently greater. If there was a segregation of the particles according to size, the data do not indicate any consistent effect of such segregation on the apparent thermal conductivities.

Conclusions

As was pointed out at the beginning of this paper, the purpose of this investigation was to construct and test an apparatus for measuring the thermal conductivity of a powdered material. The data, then, are not necessarily important beyond the indication they give as to the reproducibility of the results. It is probable that a calibrated electric heater wound in cylindrical form and equipped with suitable guard rings would constitute a more satisfactory heat source. This would have the advantages of (*a*) controlling source temperatures in ranges not suitable for a condensing vapor source and (*b*) making it possible to determine the heat flow from electrical input. In general, it may be said that in this investigation:

1. A satisfactory apparatus was developed for measuring thermal conductivity of powdered material,
2. Both the loading and conductivity data are reproducible within reasonable limits, and
3. The method is relatively simple, although limited to laboratory use.

Acknowledgments:

Many people contributed time and effort while this paper was in preparation, and the authors would like to record their gratitude. Thanks are due to Professors J. F. Bell, D. H. Fax, and R. B. Pond of the Johns Hopkins University. Mr. Robert M. Kosanke of the State Geological Survey of Illinois assisted in the photographic work.

Prof. E. A. Allcut of the University of Toronto was kind enough to read the manuscript and to offer many useful suggestions.

References

(1) S. Nukiyama and Y. Itahashi, "Measurement of Thermal Conductivity by Cylinder Method," *Transactions*, Soc. Mechanical Engineers of Japan, Vol. 2, No. 8, August, 1936, p. 595.

(2) S. Nukiyama and Y. Tanasaw, "On an Electric Tank Experiment for the Flow of Heat, Axial Symmetry About an Axis," *Transactions*, Soc. Mechanical Engineers of Japan, Vol. XXXIII, No. 3, September, 1930.

(3) E. A. Allcut, "Thermal Conductivity Tests and Results," *Bulletin* No. 182, University of Toronto, p. 7 (1949).

(4) C. L. Norton, "Apparatus for Measuring Thermal Conductivity of Refractories," *Journal Am. Ceramic Soc.*, Vol. 25, No. 15, p. 451 (1942).

(5) E. F. Grundhofer, "The Guarded Plate Heater Method of Testing Low-temperature Insulators Compared with Several Box Methods," *Mechanical Engineering*, Vol. 48, No. 11a, p. 1333 (1926).

(6) A. A. Potter, J. P. Calderwood, A. J. Mack, and L. S. Hobbs, "The Heat Insulating Value of Cork and Lith Board," *Mechanical Engineering*, Vol. 42, p. 624 (1920).

(7) R. Lander, "Factors Affecting Thermal Conductivity," *Paper No. 49*, Engineering Experiment Station, University of Minnesota, July, 1949.

Appendix

TABLE III.—ESTIMATE OF DISTRIBUTION OF PARTICLE SIZE IN POWDER SAMPLES.

Powdered Material	Size, μ	Per cent of Sample in Size Range
Calcium carbonate	Below 1	58
	1 to 3 inclusive	37
	Above 3	5
Zinc	Below 1	34
	1 to 3 inclusive	42
	Above 3 to 5 inclusive	18
	Above 5	6
Copper - copper oxide eutectic	Below 40	46
	40 to 70 inclusive	24
	Above 70	30
Carbonyl iron	Below 3	18
	3 to 6 inclusive	54
	Above 6 to 8 inclusive	26
	Above 8	2

Direct Explosion Test to Evaluate Load-Carrying Capacity of Welded Steel Structures*

By G. S. Mikhalapov[1]

EVALUATION of load-carrying characteristics of structures is usually based almost entirely on two factors: elastic stress analysis and yield strength of materials as determined by the standard tension test. A vast amount of rigorous mathematical analysis has carried the theory of elasticity to the point where stress systems can be readily calculated for a variety of structures and loads. The calculations are, of course, valid only within the elastic limit of the material so that the yield strength, rather than the ultimate strength, limits in effect the working stresses within the structure so designed.

Paradoxically enough, plastic ductility, even though it does not enter the stress calculations, has been considered an important and desirable property of structural materials, and materials with high ductility have been usually favored by structural designers. However, the mechanism of translation of high ductility into improved structural performance is not clearly understood, and in practice the designer usually contents himself with regarding steel, together with other structural materials, as being entirely isotropic and possessing essentially constant mechanical properties regardless of size and geometry. As a result, tension and compression tests of small laboratory-type specimens have been generally accepted as indicative of performance of material under actual service conditions.

In recent years, service performance data of many types of structures have begun to draw attention to the fact that the assumed state of all elastic stress is only an approximation and that most structures undergo plastic deformation at certain critical points of stress concentration during some time of their life. Furthermore, considerable evidence is appearing pointing out that the maximum load-bearing capacity of a structure is a direct function of its ability to undergo plastic deformation at such points of stress concentration without fracture, and cannot be always predicted on the basis of tests utilizing uniformly stressed small-scale specimens.

Failures of pressure vessels, ships, earth-moving machinery, and many other structures can be attributed in many cases to poor ductility of structural materials under certain conditions of stress. Furthermore, it appears that the conventional ductility of materials as determined by percentage elongation of a standard 0.505-in. tension test specimen is not necessarily indicative of the measure of ductility exhibited by the material when fabricated into a rigid structure (1)[2].

A need has therefore arisen to find a way of predicting the relative load-carrying performance of structural materials without recourse to actual destructive testing of full-scale prototypes.

The development of the direct explosion test has been undertaken as a partial answer to such a need, at least in so far as welded steel structures are concerned (7).

History

The inadequacy of existing mechanical testing methods in predicting service performance of steel structures was first recognized in the case of structures subjected to shock loading wherein the need of compromise between performance and weight dictates acceptance of permanent deformation in cases of severe loads. Armored military vehicles and naval vessels offer one example of this type of structure, and the development of a direct explosion test was first undertaken in an attempt to evaluate the performance of welded alloy steels under ballistic shock.

In general, ballistic bombardment produces two types of loading: one, a direct hit of an armor-piercing projectile, usually resulting in either destruction of the projectile or in penetration of the member hit; and two, a glancing blow of a solid projectile, or a direct hit of a high-explosive shell, producing a more generally distributed stress system. It has been demonstrated that resistance to projectile penetration is a direct function of the hardness of the plate, while the resistance of steel and steel structures to the second, less-concentrated type of shock loading cannot be readily predicted on the basis of the conventional mechanical test, with the possible exception of the V-notch bar impact test. The latter appears to correlate to some extent with actual service performance of homogeneous plates, but its acceptance for this purpose has not become general as yet even for prime plate, while it is conceded that it is not adapted for evaluation of performance of joints.

Accordingly, resistance to shock of steel plate and weldments has been generally determined by actually subjecting full-scale sections of prime plate and of typical joints to ballistic bombardment. This method of testing, besides being extremely costly and requiring large quantities of material, has a number of limitations of range, accuracy, and reproducibility; and the development of the direct explosion test was undertaken in an attempt to overcome these limitations while still employing essentially the same method of loading. In that respect the development was entirely successful, the performance of steel plate and weldments under the test correlating very closely with their performance under the ballistics test.

In the meantime, failures of ships and of pressure vessels at load levels well within the design limit have emphasized the inadequacy of the conventional mechanical test in predicting performance of steel plate even in structures subjected to conventional static or dynamic loading. Extensive research indicated that the apparent cause of these failures was the inability of the steel plate to undergo plastic deformation at points of high stress concentration, occurring whenever imperfect design or workmanship produced an abrupt change in geometry of a load-carrying member. Further experimental work suggested that this inability to undergo plastic deformation with resultant brittle fracture is caused by low ductility exhibited by certain materials in the presence of biaxial tensile stress in the plane normal to the direction of the main tensile stress. Such second and third dimensional stresses are not necessarily the result of external forces but will usually develop at any point or line of severe strain gradient. A classical example of this type of three-dimensional stress is the stress system at the root of any sharp

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* Presented at the Fifty-third Annual Meeting of the Society, June 26-30, 1950.

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[2] The boldface numbers in parentheses refer to the list of references appended to this paper.

notch, and because of this the entire phenomenon of low ductility in the presence of two stresses normal to the major stress is frequently termed notch sensitivity. This phenomenon appears to be a function of the internal structure of materials, and of their temperature, and is but one aspect of the mechanism of plastic flow and of fracture of metals (5).

In practice, notch sensitivity manifests itself in two ways: first, notch-sensitive metals will fracture in a brittle manner at the root of the notch or under a state of triaxial tensile stress; second, the fracture, after originating as a crack at a point of triaxial tensile stress, will produce its own state of triaxiality and will propagate in a brittle manner, with virtually no energy input, indefinitely until the metallic continuity of the fracturing member ends. Conversely, notch-insensitive or notch-tough metals will sustain large plastic deformation at the root of the notch prior to fracture, and, after fracture originates, its propagation will require large quantities of additional energy since it will be continually preceded by a large amount of plastic strain.

Since the conventional tension test is of little use in evaluating notch sensitivity, a number of different types of specimens have been devised and tested in the recent years in an attempt to study and understand the influence of notch sensitivity on load-carrying capacity of structures.

In general, these tests have correlated reasonably well with each other and with destructive tests of full-scale sections of actual structures such as decks of ships. However, one difficulty with such tests has been that they depend on a geometrical stress raiser to produce the desired stress and, consequently, are capable of testing only the notch sensitivity of homogeneous materials, whereas virtually all fractures in service originate at or in close proximity to welded joints which are composed of a variety of different metallurgical structures.

Since fractures, after originating at a weld, usually propagate through material unaffected by welding, the notch tests do evaluate the fracture propagating property of materials and thus predict the extent of failure that can be expected in a structure once initial fracture has taken place. Unless, however, an assumption is made that notch sensitivity of a welded joint is the same as that of the prime plate, evaluation of the maximum load-carrying capacity of a structure prior to initiation of a fracture is hardly justified on the basis of the notch tests alone. Unfortunately, to date, ample evidence exists to refute such an assumption.

There exists then a need for a test which would evaluate notch sensitivity of materials without the use of notches or other geometrical stress raisers which in effect produce the desired state of triaxial tensile stress in a very small portion of the specimen and thus limit its use to homogeneous material.

As previously mentioned, V-notch bar impact test data appeared to correlate reasonably well with both the ballistic and direct explosion test data in determining shock resistance of alloy steels. It seemed to be reasonable to suppose that equal correlation between direct explosion test and various notch-sensitivity tests could be expected. Accordingly, an extensive investigation was undertaken under the sponsorship of the Bureau of Ships, of the Department of the Navy, to determine applicability of the direct explosion test to evaluation of load-carrying capacity of structures.

The results indicate that, after proper modification, the test appears to evaluate notch sensitivity of structural steel plate satisfactorily and to correlate closely with other notch-sensitivity tests. In addition, it can be applied to testing of welded and other types of joints, thus permitting for the first time a direct comparison between performance of homogeneous and fabricated sections under triaxial tensile stress.

At the present moment, work is continuing on applying the test to various types of joints in an attempt to determine their relative performance.

Description

The direct explosion test consists essentially in applying a high velocity blow normal to, and at the center of, a flat, square plate supported along its four edges. Such a blow, or impact, will produce first a compressive elastic stress in the area over which it is applied, which will travel with the speed of sound to the back of the plate, from which it will be reflected as tensile stress and travel toward the front of the plate. The compressive stress is made possible by the resistance of the plate to the force of the blow, caused partly by the inertia of the plate and partly by the reaction of the supports at the edges of the plate. This reactive force is transmitted by progressive shear from the point of impact to the supporting edges and results in a bending moment which, in turn, produces a state of biaxial tension in the back of the plate normal to the compressive-tensile stresses produced by the original blow. If the length, width, and thickness of the plate are considered as its X, Y, Z coordinates, respectively, the stress system can be envisaged as alternate compression and tension along the Z axis, and biaxial bending along X, Y axes with the neutral axis initially somewhere near the middle of the thickness of the plate.

The magnitude of all stresses will be a function of time; however, the Z axis stress will occur virtually instantaneously, while the bending stresses along X and Y axes will increase at some finite rate which will be a direct function of the acceleration of the impacted area.

Theoretical analysis of the Z stress during the initial period before the XY stress has exceeded the yield strength, or before plastic deformation in XY plane, or dishing of the plate takes place, is possible and has been attempted by E. Saibel (2). He postulates that the elastic compression-tension wave is followed by a plastic compression wave traveling at a lower rate of speed, in turn followed by a release wave which occurs when the external force or pressure of the original impact ceases.

The various stress waves interact in a complex manner and Saibel demonstrated that spalling or tensile fracture along Z axis occurs at certain combinations of duration and magnitude of the force of impact. In general, the higher the magnitude and the shorter the duration of the impacting force, the greater the tendency to spall.

Analysis of the stress system during the second stage, or when general deformation takes place, has not been attempted so far because of the complexity of the system and lack of knowledge of the factors applicable to such a state. However, it will be readily seen that it will follow a certain general pattern. Thus, the stress system in the plane of the plate will begin as simple biaxial bending with the neutral axis somewhere near the middle of the thickness of the plate. As plastic deformation takes place, the elastic shock wave travels back and forth along the thickness axis, as alternate compression and tension. Thus, unless this shock wave decays very rapidly, an increasingly larger volume of the plate will be thrown periodically into triaxial tension. Since the stresses in the plane of the plate are continually rising while the stress along the thickness axis is decreasing, the ratio of the three stresses is continually changing.

A question naturally arises as to whether the third or thickness stress is sufficiently large at the time the biaxial stress in the plane of the plate approaches the fracture stress to be of any significance. This question was of academic importance as long as the high-velocity impact was considered for evaluation of shock resistance only. However, it becomes of paramount im-

portance in determining whether a high-velocity blow could be considered as producing a stress system equivalent to that of a notch. Considerable indirect evidence exists, as will be shown later, to suggest strongly that the thickness stress is a major factor in the fracture of a plate under a high-velocity blow even after a large amount of bulging or dishing has taken place.

High-velocity impact can be produced in many ways. For many reasons, the energy liberated as a result of a rapid chemical reaction presents an excellent means of producing such an impact. It requires a minimum of apparatus, it can be readily applied at any desired point, and both its quantity and rate of liberation can be accurately controlled. The simplest way to translate this energy into impact is to utilize the rapidly moving front of a detonating wave traveling through a column of explosive placed directly on the area to be tested, but not confined in any other way. This method, although it wastes a great deal of the energy liberated by the explosion, has the advantage of requiring no apparatus, and, furthermore, assures that virtually the entire energy is delivered at the same velocity. By properly shaping the charge and controlling its detonating velocity, impacts of varying energy and power can be obtained. The fact that only a small fraction of total available energy is used is of little consequence in test work, since the cost of the explosive is a small fraction of the cost of the test.

Unfortunately, complete lack of confinement produces impacts of such short duration, or of such high power, that failure tends to occur by spalling or by fracture normal to the thickness direction, and thus is not suited to development of triaxial stresses. However, a partial confinement of the charge on all free sides by means of white silica sand proved sufficient to permit the use of explosives of sufficiently low power to produce fractures with considerable dishing and without spalling. In addition, the use of sand appeared to improve the reproducibility of the results, though this effect is less certain.

The matter of the total energy delivered by an explosive charge to the support on which it is resting was of considerable concern since, if the relationship was not linear, the relative degree of performance of different materials would not be indicated by the size of the charges necessary to fracture them. Several attempts were made to measure the energy delivered by the charge by means of a ballistic pendulum, adapted for use with a sand-restrained charge. A ballistic pendulum, or mortar, is primarily intended for determining the total energy content of a unit quantity of an explosive, and is usually designed to handle a 10-g. charge completely enclosed by a chamber within the mortar and a projectile which is shot out of the mortar at the same time that the force of the explosion swings the mortar in the opposite direction. Since only the end thrust of the charge is utilized in the test, it was necessary to close off the chamber by means of a cover plate, to the outside surface of which was strapped the charge surrounded by the restraining cylinder of sand. Considerable difficulty was encountered with plastic upset of the supporting plate, and to the lesser extent of the mortar itself, which occurred even with comparatively small charges and which, in effect, absorbed an unknown and probably appreciable part of the energy delivered to the mortar. As a result, a 2-in. diameter charge was the largest charge that could be used without wrecking the mortar. Accordingly, the results are principally of interest in indicating the general relationship between the size and mass of the charge and the end thrust delivered by it. Figure 1 shows a graph of this relationship for the 1.4 and 2-in. diameter charges with and without the sand restraint.

It must be noted that the swing of the pendulum is not a linear function of the energy delivered to it since this energy is the product of the mass of the pendulum and the height to which it rises, or:

$$E_p = ML\,(1 - \cos A)$$

where L is the radius and A the angle of swing. Consequently, Fig. 1 is plotted in terms of height of rise or L(1-cos A) from which the energy measured by the pendulum can be derived by multiplying the height by the weight of the pendulum or 500 kg.

It will be noted that the relationship between the mass of the explosive column and the energy it delivers to the surface against which it detonates is essentially linear up to a certain critical mass, beyond which the effectiveness of additional mass of explosive decreases rapidly. The critical mass for a 2-in. diameter charge is more than double that of a 1.4-in. diameter charge, thus suggesting that for each charge diameter there exists a safe maximum height of column below which the relationship between mass or energy is very nearly linear.

Since it was not possible to measure the end thrust of charges larger than 2 in. in diameter, the maximum safe operating height is not definitely known for either 3 or 4-in. diameter charges.

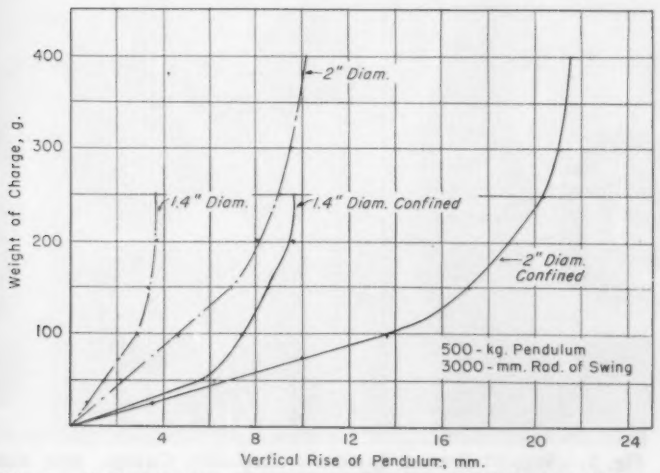


Fig. 1.—Determination of the Impact Energy of the Direct Explosion Test by Means of a Ballistic Pendulum.

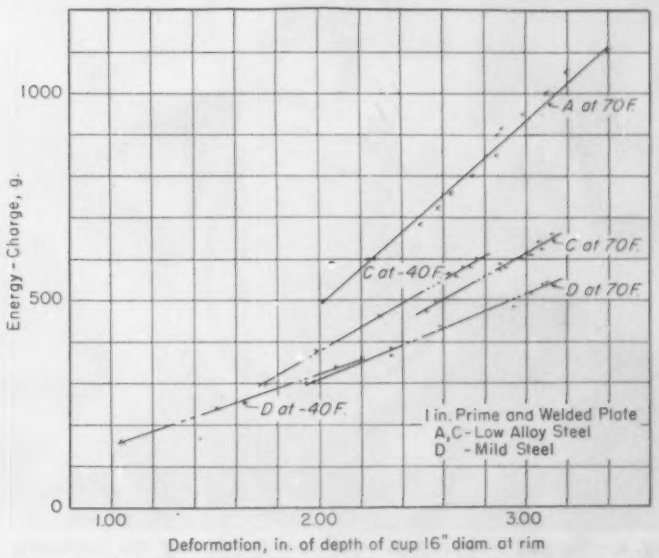


Fig. 2.—Energy-Strain Diagram of Low Alloy and Mild Steel Plate 1 in. Thick Under Direct Explosion Test.

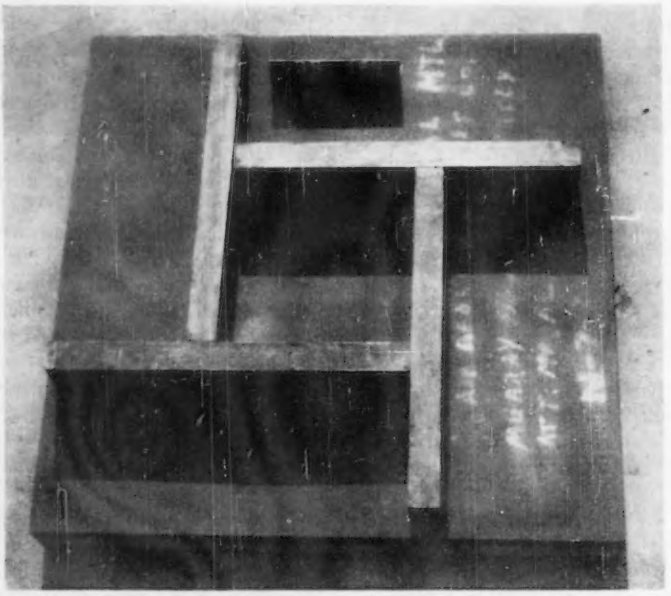


Fig. 3.—Support Frame for the Direct Explosion Test Showing Concrete Base, 3-in. Thick Alloy Steel Plate and Four 4-in. High by 2½-in. Wide Cold-Rolled Bars.

However, an examination of Fig. 2, showing the depth of deformation or of the cup in 1-in. plate produced by the 4-in. diameter charge as a function of the mass of the charge, reveals a straight-line relationship at the end of the graph up to the point of fracture. Since the depth of the cup gives the actual distance traveled as the result of the force of the explosion, this relationship would indicate a virtually constant load up to the point of fracture, which is reasonable, as the maximum reduction in area attained does not exceed 10 per cent and should be more than balanced by strain hardening.

The size and geometry of the specimen presented a considerable problem. Although the test was always envisaged in terms of a full-scale model of an actual structural section, a question arose regarding the optimum relationship between the thickness, width, and length of the specimen. In the very beginning, the significance of the stress system produced by a high-velocity impact was not fully appreciated and it was believed that the difference in performance exhibited under ballistic testing and conventional tension testing was mainly due to the difference in the rates of strain. Accordingly, the first specimens were made in the shape of a simple beam 1½ in. deep by 3 in. wide and 12 in. long. Once the velocity of detonation was reduced sufficiently to prevent spalling, these specimens behaved essentially in the same manner as under conventional static loading and failed to correlate with results of ballistic or of notch impact testing. Specimens 12, 18, and 24 in. square were then tried with ½, 1, and 1½-in. thick plate. Some difference in performance was observed between the three sizes, but all appeared to correlate with ballistic results. The 18-in. square specimen was finally chosen for 1½ and 1-in. thick plate and 12 in. for the ½-in. thick plate, primarily because welded joints require that length to develop full residual stress (2,6).

A variety of detonating velocities was tried between 5500 to 2500 meters per sec. in the form of 2, 3, and 4-in. diameter columns. In general, velocities above 5000 meters per sec. tended to cause fracture by spalling on most but the toughest of plate, regardless of the diameter or height of the charge; while explosives with detonating velocities below 3000 meters per sec. were of sufficiently low power not to produce fracture by spalling on any plate tested. The 3-in. diameter charges did not possess sufficient energy to fracture tough plate thicker than ½ in. (except by spalling in case of high-velocity explosive). Accordingly, a detonating velocity of 3250 meters per sec. was finally chosen and used in the form of 4-in. diameter column on 1 and 1½-in. thick plate, and 3 in. diameter on ½-in. thick plate.

It will be remembered that theoretical analysis of the thickness or Z stress indicates it to be a function of the

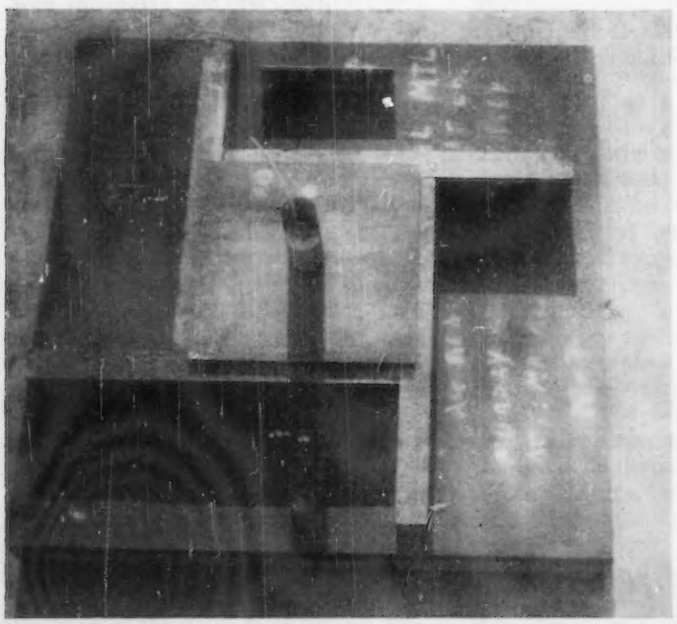


Fig. 4.—Support Frame with Specimen Supporting the Explosive Charge in Place. Part of the Cardboard Cylinder Housing the Explosive Powder Cut Away to Show Detonator.

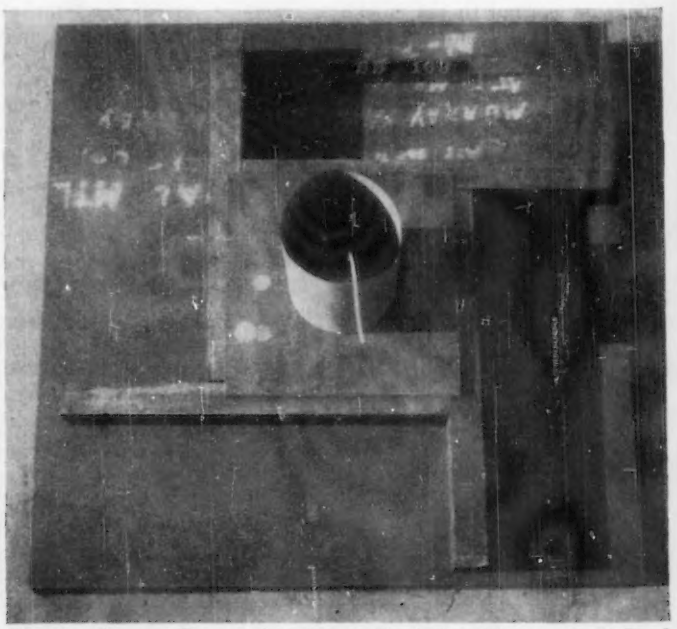


Fig. 5.—Support Frame, Specimen, Explosive Charge, and Sand Containing Paper Cylinder in Place Ready to Receive Sand.

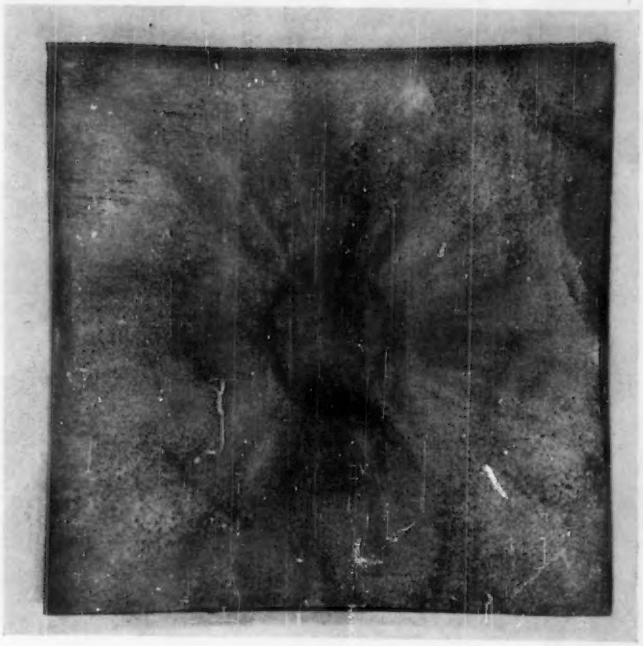


Fig. 6.—A Typical Ductile Fracture in 1-in. Thick Plate at an Energy Level Sufficient to Produce a Complete Fracture.

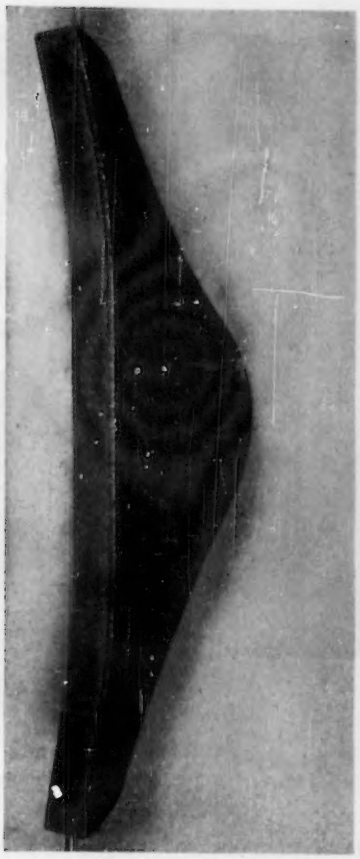
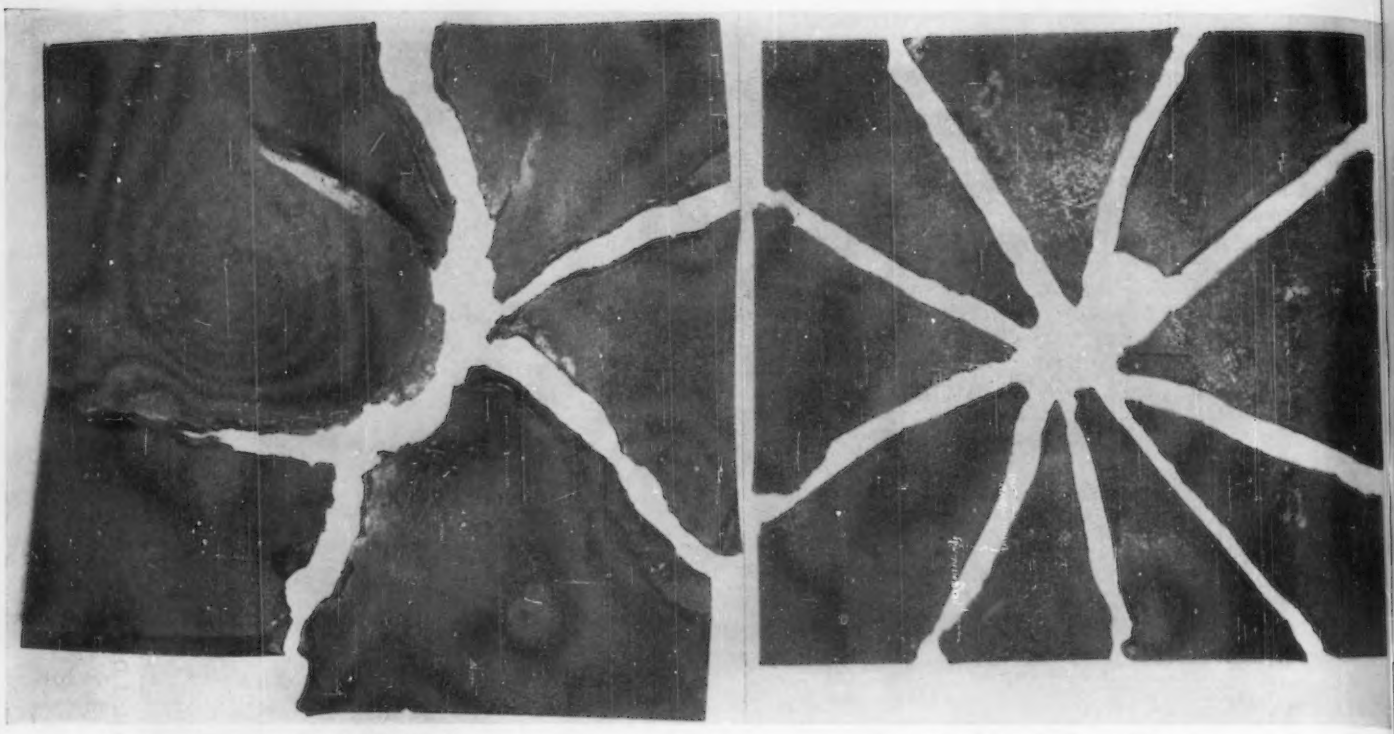


Fig. 7.—A Typical Ductile Fracture of 1-in. Plate at a Low Energy Level Insufficient to Produce a Complete Fracture.



(*a*) At Room Temperature. (*b*) At Subzero Temperature.

Fig. 8.—A Typical Brittle Fracture of 1-in. Plate at an Energy Level Just Sufficient to Initiate a Fracture.

magnitude of the power of the impact and not of its energy; or, in case of the explosive charge, of the detonating velocity and not of the volume of the charge. If increase in the third dimensional stress (in this case, *Z* stress) results in reduction of ductility, it could be expected that increase in the detonating velocity would result in the decrease in deformation prior to fracture, and hence in the net energy necessary to initiate a fracture. This is exactly what does happen, and actual test data obtained with different velocities show that both the maximum deformation prior to fracture and the energy to fracture decrease rapidly with increase of velocity. It will thus be seen that any variation in the detonating velocity can be expected to affect markedly the reproducibility of the test result.

The scatter of results produced by the variation in the velocity of detonation is further increased by the incomplete nature of the confinement of the explosion, which emphasizes the effect of the initial period of the explosion, since the restraint exercised by the loosely held sand around the charge is largely caused by its inertia and is thus relatively greater in the case of high-power explosive.

In actual testing, no reasonable consistency of results was obtained until precautions were taken to control all factors which might even remotely affect the velocity of detonation. However, once these factors were brought under control, extremely consistent results were obtained; for instance the fracture limit, that is the weight of charge just sufficient to initiate fracture, could be consistently determined within 10 g. of charge at charges varying from 500 to 700 g., or within 2 to 3 per cent.

While the total gas volume of an explosion, and therefore its total energy, is a direct function of its chemistry and can therefore be controlled with relative ease, the rate of detonation is a function of many additional variables, such as the size and shape of the powder particle, the density to which the powder is packed, the uniformity of the relative distribution of the various constituents, etc., and is much more difficult to control accurately. This, together with the fact that the required velocity of detonation is below that of commercially available explosives, has forced the use of what is virtually a custom-made explosive powder prepared under close laboratory control.

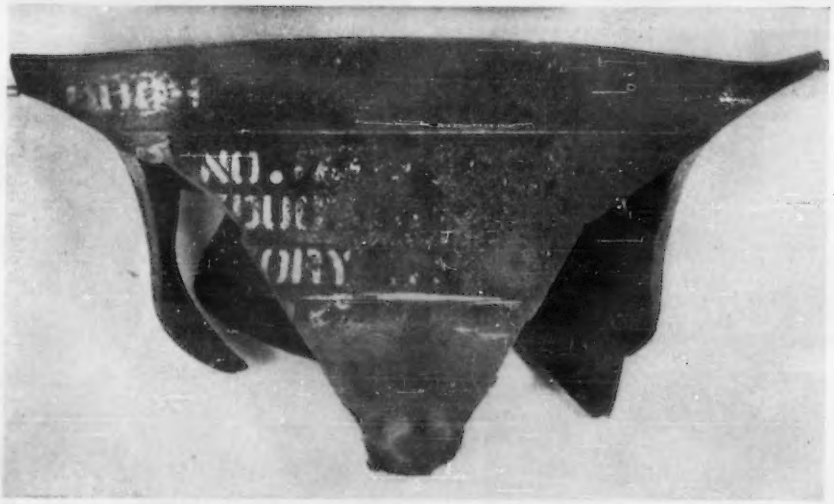
In the beginning, the specimen was supported along two of its four edges. However, in the course of the efforts to improve the consistency of reproduction of results, it was discovered that optimum results were obtained by supporting the specimen on all sides, which suggested a circular specimen as providing the most uniform stress field. However, for reasons of economy, and the fact that stress distortion in the center of the comparatively large specimens used is slight, square supports were finally chosen. They consisted of four cold-rolled steel rectangular bars 4 in. high by $2\frac{1}{2}$ in. wide laid loosely together to form a 16-in. hollow square as shown on Fig. 3. A comparison of loosely placed bars, and bars welded into a solid frame, revealed no difference in performance, and welding of frames was consequently omitted.

The inside corners of the supporting bars undergo considerable plastic upset as the result of the test, and for this reason a fresh bar edge is used for every test, at least until such time as the effects of this upset on the test are studied.

The effect of the solidity of the base on which the support rests was next explored. Little difference was found between solid concrete base and hard-packed earth resting on a reasonably close foundation of bedrock, but to eliminate every possible variable a 6-in. thick concrete base, 9 ft. square, covered by a 3-in. thick, 3-ft. square alloy steel plate was chosen.

The final procedure of the test currently in use is as follows.

A steel specimen of either prime or welded plate is supported as described above. Next, an explosive charge consisting essentially of a mixture of TNT, sodium nitrate, ammonium nitrate, and aluminum powder is packed to a desired density in a 4-in. diameter cylindrical paperboard container, the bottom end of which is sealed with a thin paper sheet. Since the density of



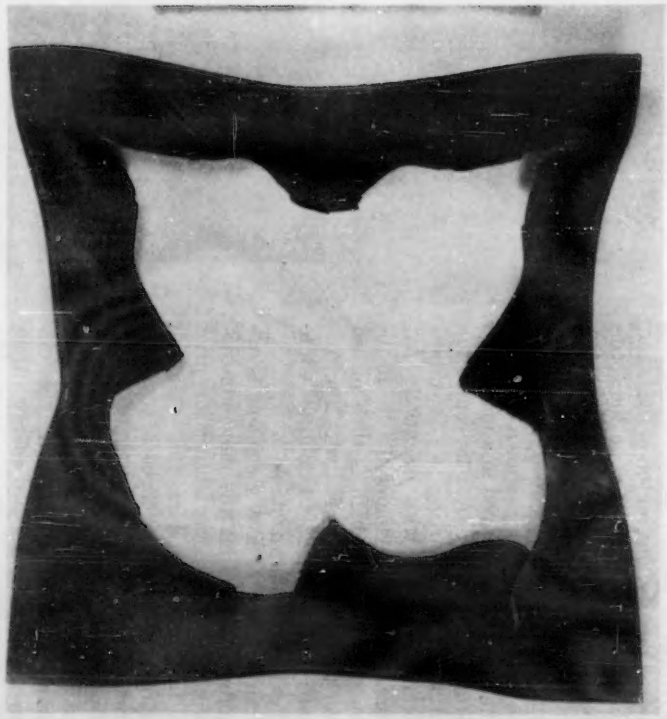


Fig. 9.—A Typical Ductile Fracture of ½-in. Plate at a High Energy Level.

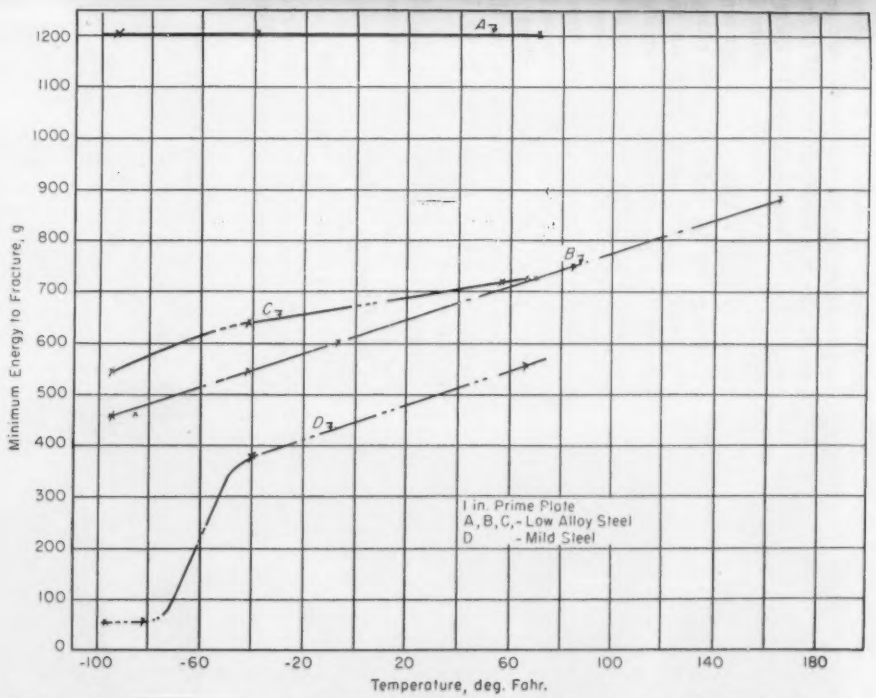


Fig. 10.—Energy-Temperature Diagram of Low Alloy and Mild Steel Plate 1 in. Thick in Prime Condition.

TABLE I.—MECHANICAL PROPERTIES OF STEELS USED.

	Steel A	Steel B	Steel C	Steel D
Type specimen	0.505	0.505	0.505	0.505
Yield strength, psi	81 000	82 000	50 000	32 000
Tensile strength, psi	100 000	100 000	90 000	65 000
Elongation, per cent	26.0	24.0	30.0	32.0
Reduction of area, per cent	71.0	70.0	65.0	65.0
Average Charpy keyhole impact at −40 F	64.0	48.0	30.0	3.0

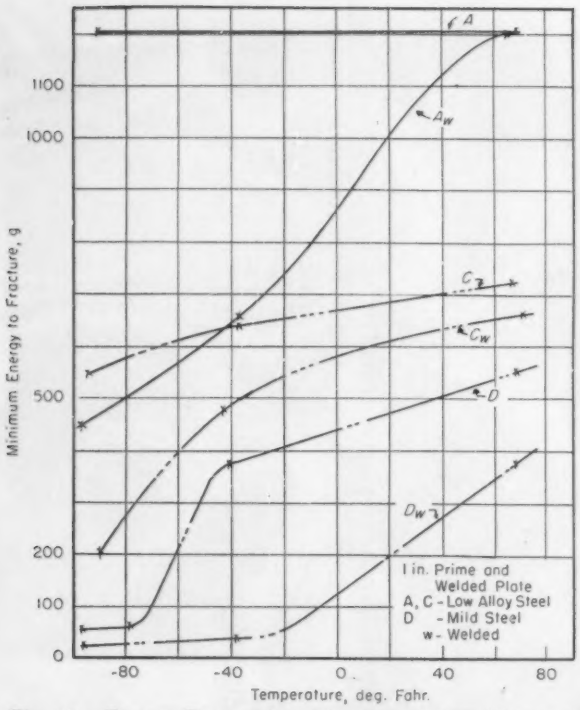


Fig. 11.—Energy-Temperature Diagram of Low Alloy and Mild Steel Plate 1 in. Thick in Welded Condition. Performance of Prime Plate Also Shown for Purpose of Comparison.

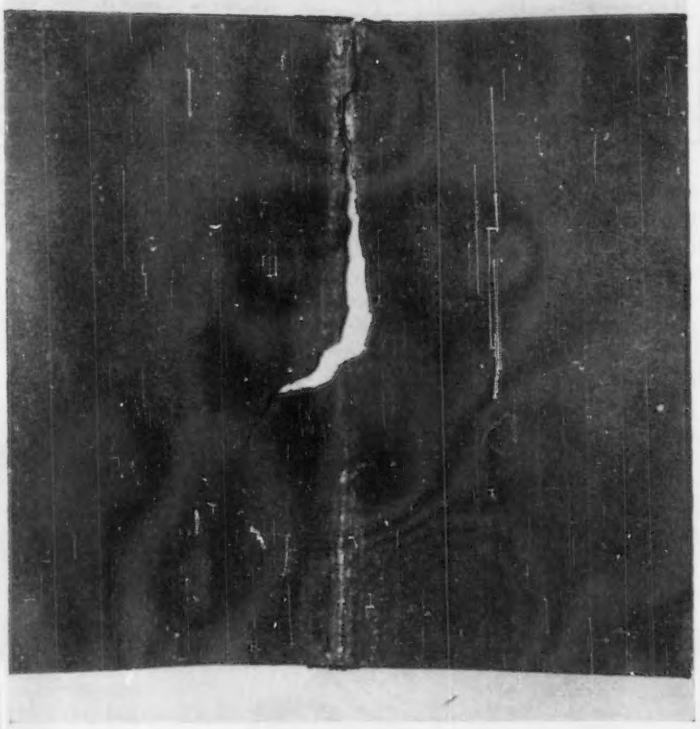
any powder is known to change in time, and since velocity of detonation is sensitive to change in density, each charge is packed immediately prior to the test by a standardized procedure using a simple weight-dropping fixture. To assure uniform density, the charge is divided into 50-g. increments, and each increment is packed separately to the desired density, one on top of the other. The charge is then placed on the specimen in its exact geometrical center, and a specially shaped detonator of primacord is placed directly on top of the explosive powder as shown on Fig. 4. The detonator is shaped in a manner to detonate the charge over its center top surface, thus starting a downward detonating wave with essentially flat front. A paper cylinder 8.5 in. in diameter and 12 in. high is then placed over the charge and filled with approximately 40 lb. of 25 to 30-mesh white silica sand, as shown on Fig. 5.

An average of five specimens is required to determine the maximum deformation and energy absorption prior to fracture as well as the minimum energy necessary to effect a complete fracture, that is, fracture extending through the entire thickness of the specimen. In the case of materials failing in a brittle manner, the difference between the two energy values is very small since once a fracture is initiated, very little energy is required for its propagation. Accordingly, the minimum energy to effect a fracture is, in practically all cases, the energy necessary to sever the plate into two or more pieces. In the cases of material failing in ductile manner, however, the energy required to propagate the fracture is relatively large and a 10 to 20 per cent difference exists between the energy necessary to produce a crack on the back of the plate approximately an inch long and the energy necessary to produce a fracture of the entire thickness of the plate and extending several inches in length. Accordingly, in the cases of ductile fractures, energy to effect a fracture was arbitrarily selected as the energy necessary to produce 8 to 10 in. of fracture through the plate.

Figures 6 to 9 illustrate the ductile and brittle types of fracture produced on $\frac{1}{2}$ and 1-in. steel plate.

Application of the Test

The original purpose of the direct explosion test was to replace the ballistic



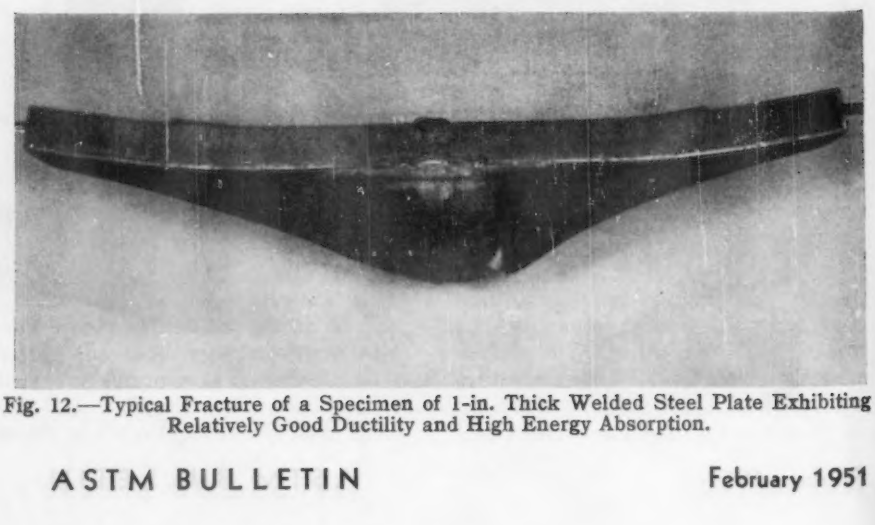


Fig. 12.—Typical Fracture of a Specimen of 1-in. Thick Welded Steel Plate Exhibiting Relatively Good Ductility and High Energy Absorption.

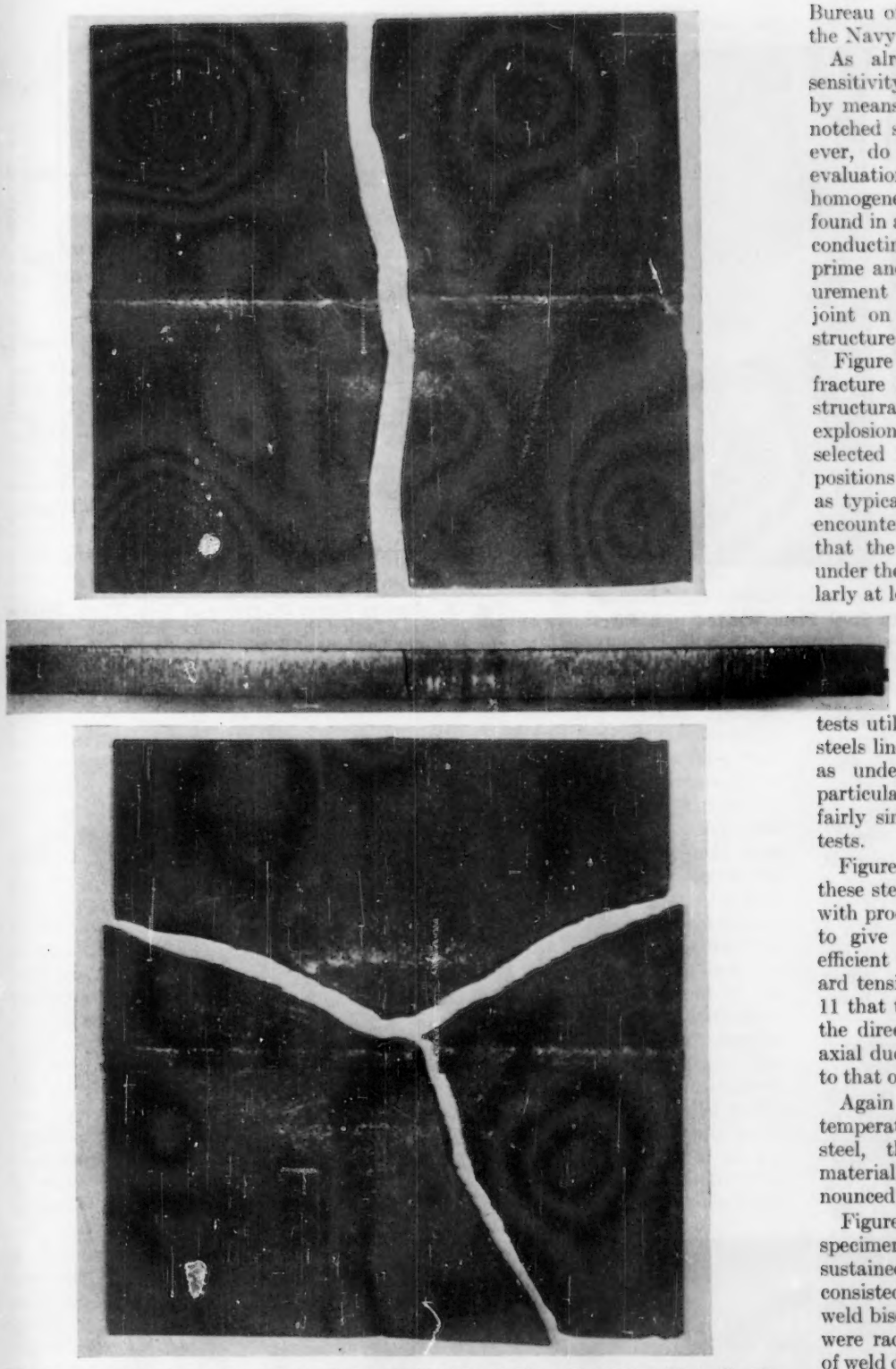


Fig. 13.—Typical Fractures of 1-in. Thick Welded Steel Plate Exhibiting Virtually No Ductility and Low Energy Absorption.

test as means of evaluating shock resistance of military structures. Actually, by the time the test development was completed, development and production of such structures had been drastically curtailed and, as a result, comparatively little actual testing has been carried out in this field. Such tests as have been conducted showed a very good correlation between the two tests for alloy-steel plate in both prime and welded condition.

By far the largest amount of test data secured to date was obtained in the course of several investigations of the notch sensitivity of structural steels for naval construction sponsored by the Bureau of Ships of the Department of the Navy.

As already mentioned, the notch sensitivity of steel plate can be evaluated by means of static tests using various notched specimens. These tests, however, do not lend themselves toward evaluation of notch sensitivity of nonhomogeneous materials such as are found in and around welded joints. By conducting explosive tests on both prime and welded plate, a direct measurement of the effect of the welded joint on the notch sensitivity of the structure can be obtained.

Figure 10 shows a graph of energy-to-fracture *versus* temperature of several structural steels tested by the direct explosion method. These steels were selected from some 14 different compositions and types investigated to date as typical of the range of performance encountered in testing. It will be seen that the performances of these steels under the test differ drastically, particularly at low temperatures, as opposed to comparative similarity of their mechanical properties as shown on Table I. When subjected to static tests utilizing a notched specimen, these steels line up in the same general order as under the direct explosion test, particularly in case of steels exhibiting fairly similar performance under static tests.

Figure 11 shows the performance of these steels when fabricated by welding with procedures and electrodes designed to give a substantially 100 per cent efficient joint as determined by standard tension tests. It is clear from Fig. 11 that this is no longer the case under the direct explosion test, and that triaxial ductility of these joints is inferior to that of the parent plate in most cases.

Again the difference is greatest at low temperatures, but in the case of mild steel, the most common structural material, the difference is quite pronounced even at room temperature.

Figures 12 to 14 show the welded specimen used and the type of fracture sustained under the test. All joints consisted of double V full-penetration weld bisecting the square specimen, and were radiographed to assure soundness of weld deposit.

It is interesting to note that in many instances the fracture is not confined to the weld zone, even though it invariably originates there at an energy value lower than that necessary to fracture prime plate.

Figure 15 shows correlation of the performance of welded joints when tested by the direct explosion test and the performance of full-scale structural models of sections of a deck of a mer-

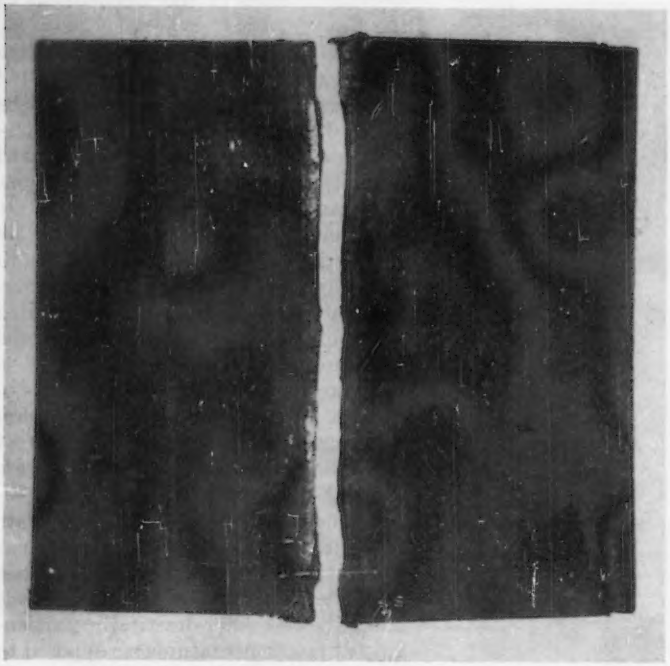


Fig. 14.—A Fracture of 1-in. Thick Steel Plate Welded with Electrodes of Lower Toughness than the Parent Plate, with Fracture Confined Almost Entirely to the Weld Metal.

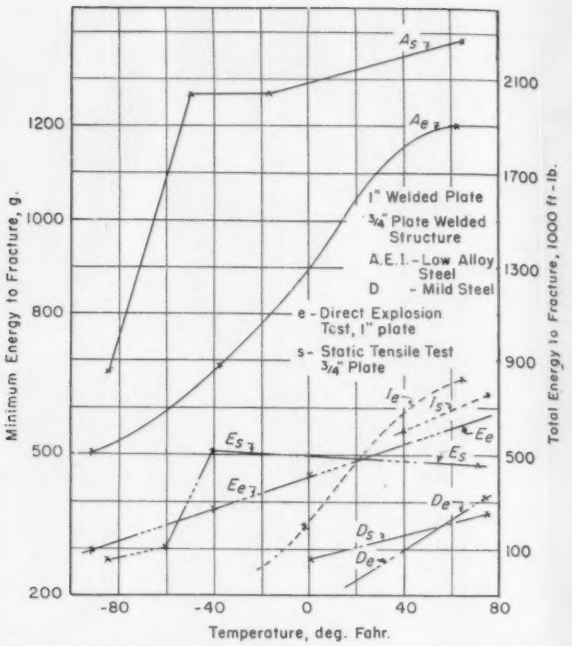

Minimum Energy to Fracture, g.
Total Energy to Fracture, 1000 ft-lb.
Temperature, deg. Fahr.
1" Welded Plate
¾" Plate Welded Structure
A.E.I. - Low Alloy Steel
D - Mild Steel
e - Direct Explosion Test, 1" plate
s - Static Tensile Test ¾" Plate

Fig. 15.—Energy Stress Diagrams of 1-in. Thick Welded Steel Plate Tested by the Direct Explosion Method and of ¾-in. Thick Steel Plate Welded Into a Model Section of the Deck of a Merchant Marine Vessel and Tested Under Static Tension.

chant marine vessel under static tension test. These models, shown on Fig. 16, were constructed and tested at the University of California as part of the investigation (3, 4) of the causes of failures of merchant marine vessels, and their tests represent the nearest approach toward actual measurement of stresses at fracture in ships. Of the steels tested, only steel A failed in a ductile manner at room temperature under both tests, all other steels failing in a brittle manner at room and lower temperatures.

It will be noted that good correlation between results of the two tests exists in the case of all steels with possible exception of steel A where the explosive test indicates a relatively poorer performance than does the static test, probably because of the fact that in the case of ductile failure the extent of fracture is not the same for the two tests. While in the case of statically loaded specimens, it is possible to continue application of energy to the specimen until the fracture severs the specimen in two parts, the direct explosion cannot produce more than approximately 9 in. of fracture in cases of ductile failure, as once the fracture forms an opening in the specimen, additional energy applied does not act on the specimen but passes through the opening.

Discussion of the Value of the Test

It has been shown that the test evaluates steel plate and weldments in an entirely different manner than do the conventional tension tests and that, in

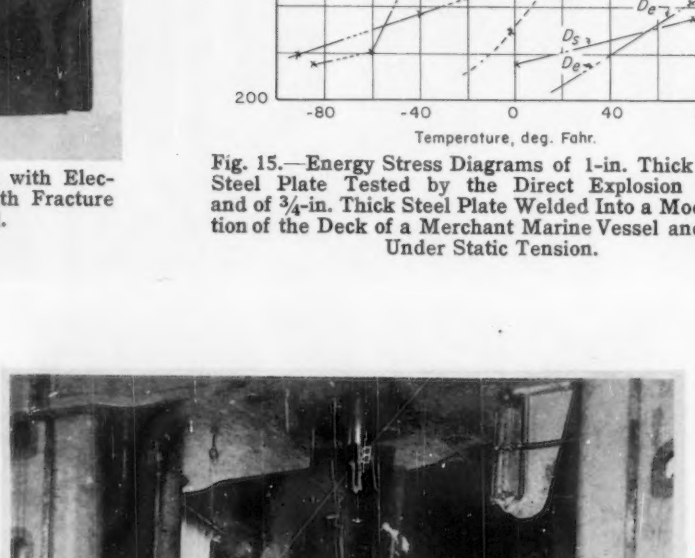


Fig. 16.—A Full-Size Model Section of the Deck of a Merchant Marine Vessel Tested Under Static Tension.

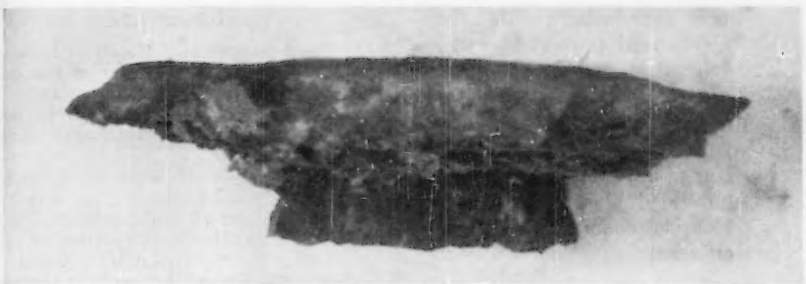


Fig. 17.—A Side View of 1-in. Thick Steel Plate Fragment Severed from a Test Plate and Corresponding Roughly to the Area Under the Charge.

general, it appears to correlate reasonably closely with mechanical tests for notch sensitivity in cases where direct comparison is possible. A question arises as to what extent this correlation may be accidental and how sound is the theoretical justification of it. Specifically, it is desirable to know to what extent the apparent inferiority of the welded joint to the prime plate, demonstrated by the test, can be expected to exist under stress conditions found in actual structures at points of stress concentrations and of steep stress gradients, under static loading. This question is extremely important from a practical consideration of the load-carrying capacities of steel structures, since its positive answer would point a way of greatly increasing their effective load-carrying capacity through improvement of the performance of welded joints. Thus, in case of steel D—a common structural material—improvement in welding over what is now recognized as the best standard procedure, to the point where the performance of the joint matches that of the parent plate, would result in the increase of the ductility and of the energy to fracture at the point of stress concentration of over 25 per cent at room temperature and of 100 per cent at 32 F. This improvement of performance at the point of stress concentration should result, in most structures, in comparable increase in the maximum safe load-carrying capacity.

If one accepts the hypothesis that poor ductility in the presence of secondary stresses normal to the major stress, such as are found at points of stress concentration and steep gradient, is responsible for structural failures of merchant marine and pressure vessels—and to date this appears to be the most reasonable explanation of these failures—the applicability of the direct explosion test rests on the premise that its effectiveness is due to triaxial tension and not to the high rate of strain.

It has been demonstrated that tensile stresses are present in the specimen, at least under the charge, along all of its three space axes, at some time during the test. However, the theoretical analysis fails to establish that the three stresses occur simultaneously or even overlap each other in time, and it may be argued that the failure is due to simple biaxial bending, the difference in performance being caused by the increased strain rate.

Considerable evidence exists, however, that this is not the case, as follows:

Figures 6 and 17 show a type of ductile fracture common in cases of specimens undergoing a maximum amount of strain prior to failure. It will be seen that fracture has taken place along a circular path on the back of the plate roughly corresponding to the edge of the charge and has penetrated approximately half way through the thickness of the plate. At this point, the fracture turns 90 deg. and proceeds to travel along the plane of the plate toward the center of the area under the charge in the manner common to fracture by spalling (Fig. 18); however, instead of extending across the entire area under the charge as in the case of a spall, the fracture turns 90 deg. before reaching the center of what would have been the spall, and travels to the front of the plate, removing a center button from the front of the plate approximately half the diameter of the charge. The significant fact is that the fracture in the XY plane and perpendicular to the Z axis does not extend all the way under the charge, but is confined to an annular ring. Thus, it could not have occurred at an early period when stress Z was at its maximum but must have taken place simultaneously with or after the occurrence of the fracture perpendicular to the plane of the plate, which indicates that appreciable Z stress existed at the time X and Y stresses were at their maximum.

Both theoretical analysis and actual observation of the extent of spalling when it occurs indicate that little Z tensile stress exists outside of the area under the impact, and it therefore appears reasonable to conclude that the effect of triaxial tension will be confined to the material under the area of impact. On the other hand, it also appears reasonable to believe that the rate of strain of any unit volume of the specimen is a direct function of the magnitude of the strain only, since the time during which strain occurs is virtually constant for the entire specimen. Thus, the effect of the triaxial tension and of the high rate of strain may be separated from the effects of biaxial tension and the high rate of strain, since the former condition prevails only in the material under the charge, while the latter exists in the material immediately outside of the charge.

It was therefore concluded that if high rate of strain was primarily responsible for the inferior performance of the welded joint as compared to that of the prime plate, no difference in performance could be expected regardless of whether the joint was placed under the charge or adjacent to the charge. Accordingly, a number of specimens were prepared with a circular weld of approximately the same length as that of the weld of a standard specimen, encircling the area under the charge but lying wholly outside of it. On testing these specimens, it was found that the maximum strain of these welds prior to fracture was considerably greater than that of welds in the conventional specimen and that the fracture occurred at substantially the same energy input as in the case of the prime

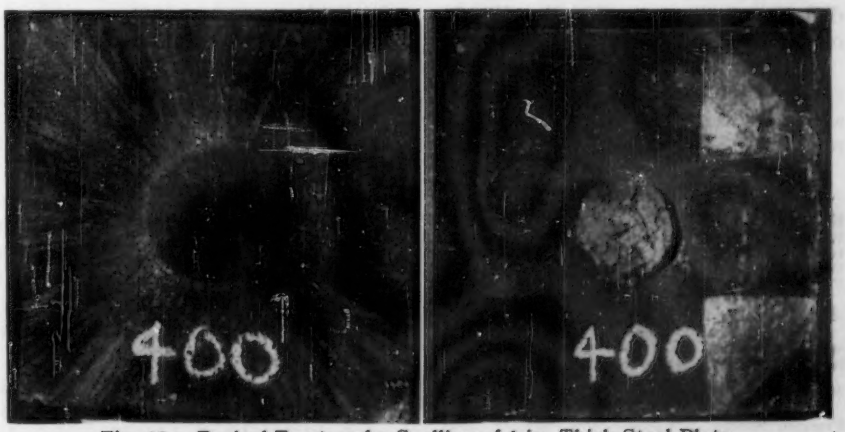


Fig. 18.—Typical Fracture by Spalling of 1 in. Thick Steel Plate.

plate specimens. As a check, another set of identical circular specimens was tested with the charge offset 1½ in. from the center and covering part of the weld. These specimens failed at substantially the same energy input and with approximately the same deformation as did the standard specimen. Accordingly, it was concluded that welded joints subjected only to biaxial tension at very high rate of strain behave substantially in the same manner as the prime plate, and that the high rate of strain alone cannot explain the difference in performance found between the welded joints and prime plate under the explosion test.

Conclusions

1. A test has been developed permitting evaluation of performance of homogeneous and nonhomogeneous materials when subjected to:

(*a*) High rate of loading.
(*b*) Combined effect of triaxial tension similar to that found at notches and other points of severe stress gradient and concentration.

2. When subjected to the test, a number of different types and grades of steel plate 1 in. thick exhibited:

(*a*) A wide difference in performance not correlating with their mechanical properties, but in general, correlating with notch-impact properties.
(*b*) A wide difference in performance, particularly at low temperatures between welded and unwelded plates of otherwise identical chemistry and properties.

3. The test shows a good degree of correlation with results of static loading to destruction of full-scale model sections of ship decks.

Acknowledgment:

The experimental work on which this paper is based extended over a period of 8 yr. and is still continuing. It was originally sponsored by the Office of Scientific Research and Development and, after the cessation of hostilities, by the Department of the Army, by the Department of the Navy, and by the Ship Structure Committee.

Although the work has been conducted under the author's general supervision, its success has been largely due to the efforts of William A. Snelling of the E. A. Thorne Enterprises, Inc., W. O. Snelling of Trojan Powder Co., A. Muller and William Benz of the Air Reduction Sales Co., and E. Saibel of the Carnegie Institute of Technology.

References

(1) Final Report of a Board of Investigation convened by order of the Secretary of the Navy to inquire into "The Design and Methods of Construction of Welded Steel Merchant Vessels," July 15, 1946.
(2) A. Muller, W. R. Benz, W. A. Snelling, and Edward Saibel, "Final Report on Application of the Explosive Test to Evaluate Shock Properties of High Yield Strength Steels," *Serial No. SSC-29*, Committee on Ship Construction, Division of Engineering and Industrial Research, National Research Council.
(3) E. Paul DeGarmo, J. L. Meriam, and M. P. O'Brien, "Causes of Cleavage Fracture in Ship Plate: Hatch Corner Tests," *Serial No. SSC-5*, Committee on Ship Construction, Division of Engineering and Industrial Research, National Research Council, October 23, 1946.
(4) E. Paul DeGarmo, "Tests of Various Designs of Hatch Corners for Ships," *The Welding Journal*, March, 1948.
(5) A. Boodberg and E. R. Parker, "Transition Temperatures of Structural Steels," *The Welding Journal*, April, 1949; also Ship Structure Committee, *Serial No. SSC-28*.
(6) W. A. Snelling, "Direct Explosion Test for Armor and Ship Plate: Prime and Welded Plate Tests," *Serial No. SSC-4*, Committee on Ship Construction, Division of Engineering and Industrial Research, National Research Council, August 30, 1946.
(7) G. S. Mikhalapov, "Structural Strength of the Welded Joints," Adams Lecture, 1947, *The Welding Journal*, Vol. 27, No. 3, pp. 193–206 (1948).

A Mechanical Wear Test Using Fission Fragments[1]

By David H. Frisch[2] and Jules S. Levin[3]

Radioactive tracers have been used[4] in studies of the wearing away of rubbed surfaces. The main difficulties encountered in utilization of tracer techniques are as follows.

1. The whole object may be made sufficiently radioactive so that there is appreciable activity in the small amount removed. This necessitates either making it originally partly out of highly radioactive material, or giving it appreciable neutron bombardment later, probably in a pile. If the wear is small there is only a very slight diminution of the activity of the worn object, for example, the steel spindle of a lathe, so that the test must be of the activity in the lubricant or on the wearing surface, for example, the spindle bearing.

2. A thin surface layer of radioactivity may be applied by (*a*) electroplating, which may change the surface characteristics of the material, or (*b*) inducing surface activity by proton or deuteron bombardment with a positive ion accelerator.

A simpler variant of 2(*b*) is discussed in this paper. Radioactive fragments of nuclei that have undergone fission close by penetrate the surface to be studied. The depth of this surface layer cannot be greater than the maximum range of fission fragments in the material to be worn but can be made less if desired by removal of the foil containing the fissionable nuclei to a greater distance. The activity could possibly be buried in a layer below the surface by collimating the fragments from a thin source.

This radioactivity may be applied to any surface, penetrating a depth of from approximately 2 mg. per sq. cm. of material with low atomic number Z, to 12 mg. per sq. cm. for high Z materials.[5] The fissionable material must have a large fission cross-section compared to the cross-section for neutron

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[1] Research carried out under contract with the Atomic Energy Commission.

[2] Now at Massachusetts Institute of Technology, Laboratory for Nuclear Science and Engineering, Cambridge, Mass.

[3] Now at Cornell Graduate School, Ithaca, N. Y.

[4] J. T. Burwell, Jr., "Radioactive Tracers in Friction Studies," *Nucleonics*, December, 1947, p. 380.

[5] E. Segré and C. Wiegand, "Stopping Power of Various Substances for Fission Fragments." *The Physical Review*, Vol. 70, p. 810 (1946).

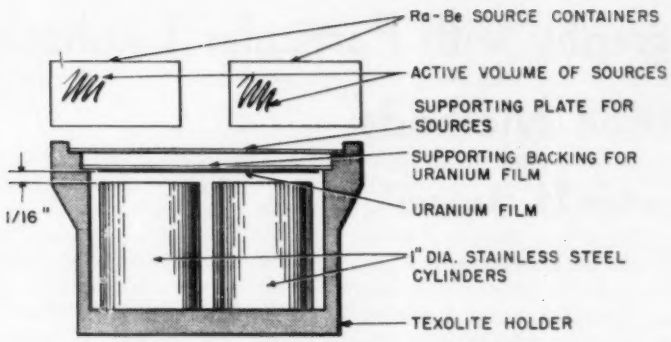

Fig. 1.—Experimental Setup for Irradiation.

capture of the material to be worn, or else the background activity from the bulk of the material will mask the activity of the fission fragments. In practically all cases, this requirement may be met by the use of an enriched U-235 or plutonium foil. In some cases an ordinary uranium foil may do if sufficient neutron flux can be provided.

Experimental Procedure

In order to check this method, the wear of a plane surface was measured mechanically and also by the diminution of fission fragment activity in its surface. This constitutes a rough experimental calibration of the radioactive wear test for the particular material and irradiating geometry used.

Two similar stainless steel cylinders approximately 1 by 1 in. were irradiated with fission fragments in the setup shown in cross-section in Fig. 1. Two 1-g. radium-beryllium neutron sources were placed above a highly enriched fission foil of approximately 1 mg. of U-235 per sq. cm. The fission foil was placed above the tops of the cylinders, separated from them by approximately $\frac{1}{16}$ in. The assembly was placed in a large can of paraffin to slow down the fast neutrons produced by the source. The exposure time to neutrons was $16\frac{1}{2}$ hr., an entirely arbitrary figure which might be chosen from minutes to months, depending on the time-scale of subsequent wear-testing. The flux of neutrons was approximately 10^4 per sq. cm. per sec.

The cylinders were then removed and the activity of both their tops and bottoms measured over a period of approximately a week with a halogen-filled Amperex thin window counter. The bottoms of the cylinders showed an activity with a half-life of from two to three hours which died away to less than 10 per cent of background in about a day. This was probably the well-known neutron-induced manganese β-decay.

At approximately 105 hr. after exposure, one of the cylinders was worn down by lapping by hand on a cast iron lapping block, using levigated alumina abrasive. The amount removed was measured by comparing the cylinder height with standard gage blocks, using a Sheffield reed comparator. The activity of the worn sample was compared with that of the control sample, approximately 70 counts per minute (70 cpm.) above a background of 20 cpm. It should be noted that the active region of the counter may not have covered the full area of the top of the cylinder.

This process of lapping and measuring was repeated two more times, the last at approximately 125 hr. after exposure. The results are displayed in Fig. 2. The ratio R of counts above background for the worn sample to that for the control has been normalized to unity at zero wear depth. The actual observed ratios were greater than those plotted by a factor of 1.09, due possibly to unsymmetric location of neutron sources or nonuniformity of uranium film thickness. The normalized R is plotted here as ordinate, and wear depth in units of tenths of thousandths of an inch as abscissa.

The exact shape of the curve is not given by these few points, but the initial slope gives a good measure of the usefulness of this method. The counting rate decreases approximately 8 per cent (in this case 5 cpm.) for each 10^{-5} in. removed. By repeated applications after wear, one could stay in a region of high sensitivity if desired.

The small but possibly significant counting rate above background at 3.7×10^{-4} in. depth, well beyond the 2.3×10^{-4} maximum range of fission fragments, may be due to diffusion of fragments into the metal, or perhaps to some folding-under of outer layers of metal. For industrial applications in which the worn surface gets hot, this might be a serious difficulty with the technique and might warrant a more careful study.

Conclusion

A "hot patch" of surface radioactivity is applied locally to a surface by placing an enriched fission foil near the surface and irradiating the fissionable material with neutrons from a source surrounded by a moderator such as paraffin, water, or oil. The method is adapted to measuring wear depths of from a few millionths to a few ten-thousandths of an inch of dense materials, and up to a mil of lighter materials such as plastics. Wear may be measured at times from minutes to months after irradiation. The total amount of induced radioactivity involved is negligible from a health standpoint.

Acknowledgment:

Thanks are due to A. J. Beckwith of the Brookhaven National Laboratory Machine Shop for lapping and measuring the sample.

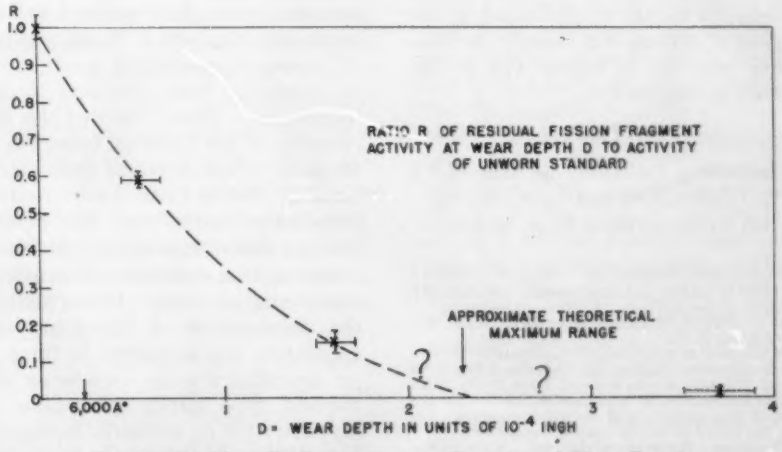

Fig. 2.—Residual Radioactivity as a Function of Wear Depth.

An Evaluation of Radiography with Particular Emphasis on Detection Methods[1*]

By Carlton H. Hastings[2]

SYNOPSIS

Past trends of development, the present status, and suggested future trends in industrial radiography are discussed. Techniques employing radiation methods for producing inspection data of greater reliability and at faster rates than now possible are suggested.

Considerations of the application of radiographic inspection methods to mass production seems to dictate the need for basic modifications of the method, if bottlenecks in production are to be avoided. In particular, modifications which permit automatic or semiautomatic procedures and reduction in operational costs are believed necessary to this objective. Improvements in both the versatility and economy of radiography can be brought about by providing a fast, remote image detection method.

The application of television techniques to produce a picture quickly, to eliminate the expense of film and its handling, and to permit automatic, production-line instrumentation has been discussed. It is further visualized that a net improvement in picture quality may be realizable by use of such a high-speed image converter.

Although the suggested method of image formation employing a scanning electronic tube directly sensitive to X- or gamma-radiation has not been evaluated experimentally by the author, its possibility of success, based upon facts presented, seems strong. There are numerous questions that can be raised regarding the operation of such a detection system, questions that would be difficult to answer at this time. However, it is believed that they are mostly questions of an engineering nature and require only the expenditure of developmental effort to produce the answers. Since the purpose of this report is to offer basic ideas for solution of problems posed, it is therefore optimistic in tone, leaving the discussion of limitations and disadvantages to a later time.

IN DIRECTING one's efforts efficiently along most profitable lines, as measured in terms of the usefulness of accomplishments per hour expended in their development, it is necessary to pause frequently and review past trends of development, present status, and future objectives. The author has attempted to do this in the case of the radiographic method of non-destructive testing. The result of this consideration has been a number of ideas, which are believed worthy of statement for the purpose of stimulating thought and obtaining reactions of others who are interested in this field.

PAST TRENDS

Penetrating radiation, as utilized for the non-destructive testing of materials, has, up to the present time, meant X-rays and radium emanation, the greater application being made of the former type of source. Although advantages can be recognized in favor of the use of radium as a source for some work, X-rays have proved advantageous for the bulk of examinations performed. These advantages are associated primarily with the higher available intensity of X-rays and, hence, shorter exposure times. As a result of the realization of the above advantages in favor of X-ray sources, much effort has been expended on the development of X-ray generators of increased penetrating power in order to overcome their previous thickness limitations. There followed the developments of the Coolidge tube, the electrostatic or Van de Graaff generator, the General Electric 1 and 2-mev. resonance transformer units, and the Betatron. One can now obtain equipment that surpasses radium emanation in penetrating power and quantity. Concurrent with the development of X-ray generating apparatus, improvements in films used for recording images were being made. Medical type radiographic films were supplemented by industrial radiographic films offering improved image sharpness and contrast. The actual improvement afforded by the latest films commercially available, as compared with previously available medical films, is in general not great, being of the order of 30 per cent improvement in film gradient[3] at commonly used densities. It is difficult to evaluate the improvement in image sharpness which resulted from the development of fine-grained films. In general, one may conclude that the gross contributions to the art of industrial radiography have revolved around the development of X-ray machines of increased penetrating power, resulting in a slow but steady increase in the thickness of material which can be penetrated in economical periods of exposure.

PRESENT STATUS

Without presenting a complete summary of the present status of the radiographic method of examination, the following pertinent statements can be made. The radiographic method of examination has attained widespread usefulness as a tool for the development of good casting and welding techniques. Its application to production inspection has been limited by the slowness and high cost of the method to occasional spot-checking. There remain many inspection problems where 100 per cent or high percentage radiography would be desirable, if the time and cost factors could be reduced. The factors which account for the quality of a radiograph are now fairly well recognized and, within the limitations of available films, what is generally considered as adequate picture quality usually is attainable in practical radiography. Applications do exist, however, where the quality of the resulting film must be sacrificed in order to produce a picture or to produce a picture in a limited time. In practical inspection, quality may give way to economy.

SUGGESTED FUTURE TRENDS

In order to expand the scope of utility of inspection methods using penetrating radiations, the most valuable step would seem to be one which allowed significant improvement in the speed with which

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[1] The statements or opinions in this article are those of the author, and do not necessarily express the views of the Ordnance Department.

[2] Physicist, Watertown Arsenal, Watertown, Mass.

[3] "Radiography in Modern Industry," Eastman Kodak Co., X-Ray Division, Rochester, N. Y. (1947).

the data may be obtained. There are instances where a picture or radiograph is not necessary to obtain the necessary inspection information.[4] An example of this type of problem is the examination and consequent control of the thickness of sheet material such as sheet steel.[5,6,7] By using a fast detector, such as an ionization chamber, photomultiplier pickup, or Geiger counter, a quantitative evaluation of the variation of sheet thickness can be obtained. Further, the electrical signal produced by the detector may be caused to operate corrective means for adjusting the sheet thickness emerging from the rolls. The examination and subsequent corrective action in this case are almost instantaneous in operation, as well as continuous. Without creating a bottleneck in production, 100 per cent inspection of the sheet thickness is easily accomplished.

The type of inspection instrumentation just described is capable of development to a semiautomatic or fully automatic status, requiring little or no interpretation of data by the inspector. It so happens that the inspection problem for which the apparatus was designed could be handled in this manner. The limits of thickness between which the product is controlled by the machine are predetermined and set into the machine controls.

Where unsoundness of a product, such as a casting or a weld, is under consideration, the establishment of acceptance limits is not so simple a task, and the inspection machine usually cannot be supplied with the necessary data for automatic acceptance and rejection. In these cases, one must rely upon the training and judgment of the inspection personnel for proper interpretation and decision. When soundness conditions are the subject of the investigation, it is probably easier to train the inspection personnel to interpret data when they appear in pictorial form than when they appear in the form of a meter reading or cathode-ray oscilloscope pattern. In other words, it is easier to evaluate a crack with regard to its size, shape, and location if one can see a picture of the crack and its relation to the object than it is to evaluate other forms of data. This is particularly true with respect to the question of the nature of the unsoundness. The problem is also prevalent in the case of some magnetic and ultrasonic techniques where flaws may be readily detected, but identified with great difficulty—or not at all.

The foregoing probably represents the greatest single reason for the acceptance of the radiographic method of inspection. The picture on the radiographic negative tells the story. Assuming this, it would seem that plans for the advancement of radiography should not only provide for the development of greater speed of obtaining the data but should include also the thought of presenting the data in pictorial form.

Too frequently the modern radiographer openly or subconsciously expresses a desire for clearer, more brilliant pictures when straining to see the images which might be there. It does not seem that the advance to higher energy radiations has led to an improvement in picture quality. It is true that the high-voltage equipment has allowed us to get pictures through thicknesses of material which could not be penetrated at lower energy levels. In terms of so-called "radiographic sensitivity," the pictures are excellent. They reveal what is considered to be sufficiently small variations in total thickness. Nevertheless, the radiographs become increasingly more difficult to interpret as the energy used to produce the exposure is increased. One need only compare two radiographs of the same object taken at 175 and 1000 kv., for example, to see the superiority of the former over the latter, other factors being equal. To make a proper comparison, of course, the thickness of the object should be within the range of the 175-kv. machine with regard to exposure time ($1\frac{1}{2}$ in. of steel, for example). The difference is partly due to the greater absorption coefficient at the lower kilovoltage and the consequent improvement in image contrast over that obtainable with 1000 kv. The author, for one, is not pleased with the quality of the high-energy picture. It requires much more effort to see images under these conditions. It follows from these thoughts that our advanced thinking should include ways and means for improving picture quality, particularly with regard to contrast obtained through thick sections of material. When the subject of high-voltage pictures is introduced, someone usually remarks about the wide latitude or range of thicknesses which can be covered with a single exposure. The existence of this wide latitude is acknowledged, but its desirability, at the expense of picture brilliance, is questioned. One cannot have high latitude and high contrast, and since it is the contrast factor which contributes to high flaw detectability, this factor would seem more important from a picture quality standpoint. Latitude is important only from the point of view of reducing the number of exposures necessary to examine a given area, and hence reducing inspection time. Here, again, the quality of the picture may be sacrificed because of economic considerations. The reduction in inspection time can be achieved through efforts to provide a significantly faster radiation detector than presently available films. Would it be asking too much to expect that the high-speed detector also have a more variable contrast characteristic than available in present films?

To summarize the previous remarks, there are three particular channels along which it would seem most profitable to direct developmental effort:

1. Improved speed of obtaining data, in pictorial form.
2. Improved quality of pictures.
3. Greater flexibility of picture characteristics.

A Suggested Approach

It would hardly seem justifiable to express dissatisfaction with so many things concerning radiography, as has been done in the preceding section of this paper, without at least suggesting some approach to a solution of these difficulties. The ideas that follow have been considered over a period of years and appear more and more promising as technical progress in allied branches of science advances.

Improved Speed:

A method has already been described wherein the speed with which inspection data are obtained has been increased tremendously over common practices. This method, employing the ionization chamber to provide data relative to X-ray intensity, is commercially available. Its operation is instantaneous by comparison with film techniques; however, a picture of the area being examined is not obtained. One obtains only an integrated measurement of the intensity over a finite small area examined. For the application described, this type of data is all that is required. Considering possibilities beyond the available instrumentation, and where a picture is desired for purposes of interpretation, a crude sort of contour map can be formed by plotting intensity values obtained by moving the ionization chamber over the area to be inspected. If the chamber is made sufficiently small, a fairly well-defined contour map can be prepared from which gross irregularities in thickness or absorption can be outlined. As a further improvement, one might use a scintillation counter or a

[4] "Testing with X-ray Counting Tubes," *The Iron Age*, Vol. 151, June 10, 1943, p. 70.
[5] R. C. Woods and F. Fua, "Continuous Gaging with X-ray Micrometer," *The Iron Age*, Vol. 156 November 29, 1945, p. 50.
[6] W. D. Coolidge, "X-rays Control Hot Mill Sheet Gages," *The Iron Age*, Vol. 153, May 4, 1944, p. 116.
[7] C. W. Clapp and R. V. Pohl, "X-ray Thickness Gauge for Hot Strip Rolling Mills," *Electrical Engineering*, Vol. 67, May, 1948, p. 441.

solid ionization chamber such as a diamond crystal counter, arranged to provide an intensity measurement continuously (integrating rather than counting) and to continously scan the back of the irradiated specimen. By applying the signal from the high-speed X-ray intensity detector to a recorder synchronized with the scanning motion of the detector (a facsimile type of recorder), the contour map can be automatically plotted. Such a procedure has been employed by the author and his associates for plotting variations in magnetic fields by using a magnetically sensitive detecting element in place of the scintillation detector.[8]

Although mechanical scanning using a high-speed detector can be made to produce a picture, the entire operation is slowed down to an unsatisfactory pace by the mechanical operation of scanning and recording. This problem has already been overcome to a large degree in the television art.[9] It is a well-known fact that television scanning is accomplished electronically at a speed sufficient to reproduce a complete picture area at a rapid rate. In fact, the rate at which the entire picture is scanned and presented for observation lies within the bounds necessary for persistence of vision. The scanning operation is too fast to be seen easily, and the picture appears to be uninterrupted.

The scintillation detector of X- or gamma-radiation[10, 11, 12] is a relatively simple device in itself. It comprises a crystal of a material which scintillates (gives off visible light flashes) when the X-ray quanta are absorbed therein. A photomultiplier tube viewing these scintillations is capable of producing a usable electrical signal, as a result of the absorption of a single photon.

In order to realize the advantage of the fast-acting scintillation or ionization type of detector and of the fast electronic scanning of television, one can view a fluorescent or scintillation screen with a television camera tube. By means of the circuitry familiar to the television art, the visible image on the fluorescent screen can be televised and monitored at a remote location behind protective barriers. In effect, this arrangement is ordinary fluoroscopy

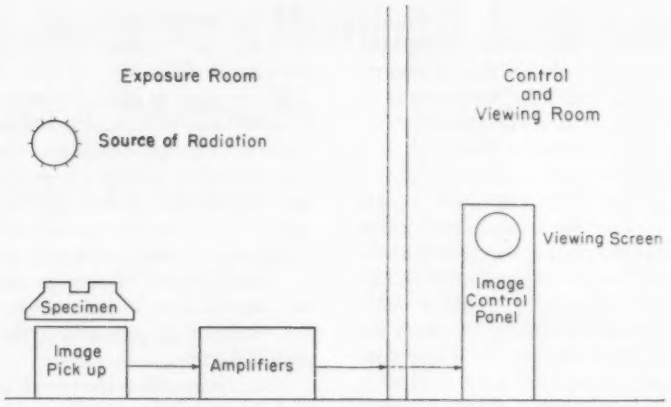


Fig. 1.—Block Diagram of Remote Image Pickup System.

with remote viewing. A recently announced development makes this arrangement seem even more interesting. A new type of television camera tube[13] has been developed, having a response sensitivity approximately equivalent to that of the eye. Previous camera tubes have been only slightly more sensitive than a fast photographic film.

The next step that suggests itself is the most interesting. It consists in doing away with the fluorescent screen in the remote fluoroscopic viewer. Because of the similarity in many respects between X-rays and light, one might imagine a television camera or pickup unit that is directly responsive to X-rays, and hence capable of producing an electron image without the intermediate conversion to a visible light image. Such a television pickup tube actually exists, but, as far as can be determined by the author, has never been used in this manner. In fact, any of the television pickup devices may be capable of producing pictures from short-wave (X-ray) radiation. One of these devices, in particular, is chosen for illustrative purposes. The device is called a "photoconductive pickup tube,"[9] and was constructed for ordinary television applications and to be excited by visible light. That such a pickup device can be successful where X-rays are employed in place of visible light has been demonstrated by some preliminary experiments designed to investigate a different method of filmless radiography. Xerography,[14] a process of reproduction developed at Battelle Memorial Inst., has been investigated with regard to its applications to radiography and as a substitute for film by R. C. McMaster.[15] This method is not instantaneous in operation but requires an exposure and processing time less than that of photographic film. It has the decided advantage that a single electroradiographic plate may be reused many times. Most important to this paper, however, McMaster's experiments demonstrate the response of photoconductive layers to X-rays and their ability to form usable electronic images. The sensitive screen of the photoconductive television pickup tube works on the same principle as the electroradiographic plate of McMaster and should therefore be capable of producing an electron image instantaneously—that is, without a so-called exposure time. Coupling this photoconductive pickup device with well-known television circuitry would then produce a visible image instantaneously and without the usual processing operation or development.

With reference to Fig. 1, the suggested method of approach to the problem of detection speed may be summarized as follows: A source of radiation irradiates the specimen giving rise to variations in radiation intensity behind the specimen in the familiar manner. A detecting device, similar to a television camera tube, but minus the optical equipment, and having an X-ray responsive screen, detects the variations in radiation intensity. By well-known methods, the electrical signal is amplified, *modified*, and presented instantaneously at a remote and safe point for viewing. Since the picture is required to be sent only to the next room, the radio transmission circuits usually employed for television, and their attendant complications, can be omitted and the picture sent over a wire to the receiving point.

This type of instrumentation should be susceptible to remote and automatic

[8] R. D. Kodis, "A Flaw Detector for Tubes," *Proceedings*, Am. Soc. Testing Mats., Vol. 50 (1950).

[9] V. K. Zworykin and G. A. Morton, "Television: The Electronics of Image Transmission," John Wiley & Sons, Inc., New York, N. Y. (1940).

[10] H. Kallman, "Quantitative Measurements with Scintillation Counters," *The Physical Review*, Vol. 75, February, 1949, p. 623.

[11] G. A. Morton and J. A. Mitchel, "Performance of 931-A Type Multiplier as a Scintillation Counter," *Nucleonics*, Vol. 4, No. 11, January, 1949, p. 16.

[12] J. W. Coltman, "The Scintillation Counter," *Proceedings*, Inst. Radio Engrs., Vol. 37, June, 1949, p. 671.

[13] V. K. Zworykin, "The Photicon," *Electronics*, Vol. 22, December, 1949, p. 65.

[14] R. M. Schaffert and C. D. Oughton, "Xeroradiograph: A New Principle of Photography and Graphic Reproductions," *Journal*, Optical Soc. of Am., Vol. 38, December, 1948, p. 991.

[15] R. C. McMaster and R. M. Schaffert "Xeroradiography, a Basic Development in X-Ray Nondestructive Testing." Presented at 9th Annual Meeting, Society for Nondestructive Testing, October, 1949.

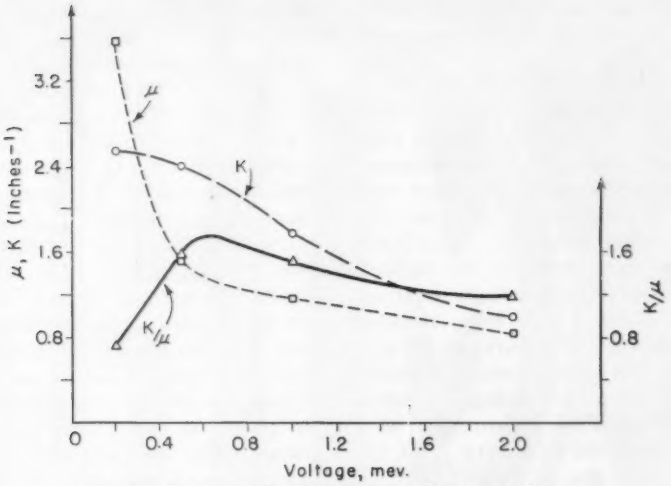


Fig. 2.—Factors Affecting Subject Contrast (Steel).

K—Scattering factor *I* scat./*I* pri. *μ*—Linear absorption coefficient. Value of *K* at 0.2 mev. after Seemann, other values of *K* after Buechner, Van de Graaff, *et al.*

operation, thereby enabling the examination of material in large quantities without introducing a bottleneck in production. The author's personal experience has indicated that the maintenance of a file of films resulting from radiographic inspection, as now practiced, is unnecessary in a majority of cases, and occupies valuable storage space. If permanent records are required, this minority of situations can be handled by 35-mm. photo-recording of the image on the monitoring tube. The initial saving in the cost of film and its processing by use of the suggested method is obvious and need not be emphasized beyond its mention.

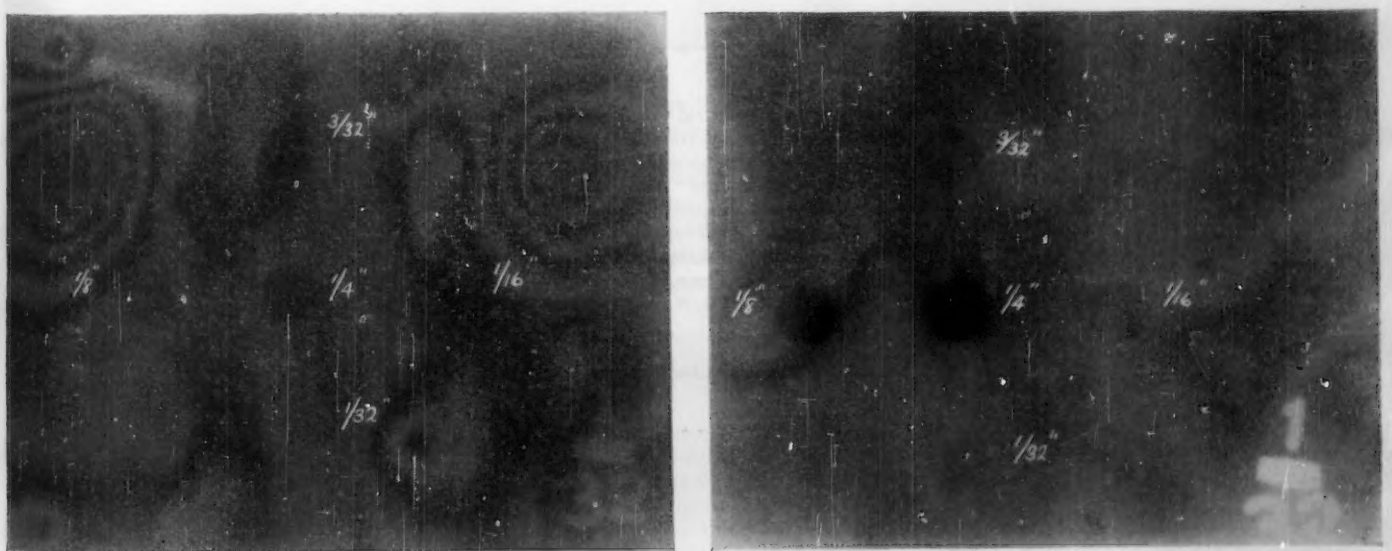
Improved Quality:

The matter of improving radiographic picture quality is intimately associated with the particular method by which the picture is produced. Since the television detection system has been suggested as a means for obtaining fast, remote, picture pickup and presentation, let us discuss the possible improvements in picture quality which may be realized with this system of detection. It can be stated that improvement in quality may be expected when television techniques are employed, because (*a*) the electronic techniques involved provide a flexibility of picture control not believed easy to obtain by other methods, and (*b*), because the high speed of response of the techniques may allow modification of X-ray procedures such as to provide higher quality pictures. Let us examine these two reasons.

Advantages Due to Electronic Technique.—In the television process, following the production by the camera tube of an electrical signal containing picture information, the signal is usually amplified and modified. The modification may consist of an adjustment of the relative amplitude of the parts of the signal such that, upon viewing the picture, its parts can show greater or less contrast. The advantages of such nonlinear amplification or clipping circuits have been described recently by Garvin and Goodwin[16] who have viewed ordinary X-ray negatives on an illuminator. The interesting feature of this note was that the viewing was performed, not with the eye directly, but by means of a television camera tube and monitor. They report striking improvements in contrast to the extent that portions of the picture which could not be seen for want of sufficient contrast when viewed directly were made visible after televising.

Advantages Due to Modified X-ray Procedures.—Earlier in this paper, some objections were raised regarding the contrast obtained in ordinary film radiographs when using high-energy radiations. It is a generally recognized rule that exposures should be made using the lowest possible kilovoltage consistent with economical exposure times. The basis of this understanding is, of course, the fact that the absorption coefficient for a given material increases with decreasing kilovoltage. Without disputing this fact, higher voltages than are necessary for penetration reasons alone are often employed in order to avoid the complications and time involved in reducing scattered radiation by blocking

[16] J. S. Garvin and C. W. Goodwin, "Electronic Enhancement of X-ray Films Contrast," *Science*, Vol. 110, November 4, 1949, p. 481.



(*a*) 1000-kv. type M film. 0.015-in. lead screens. Background density, 1.50. 3/32-in. hole density, 1.64. Contrast, 0.14.

(*b*) 175-kv. type M film. 0.006-in. lead screens. Background density, 1.25. 2/32-in. hole density, 1.53. Contrast, 0.28.

Fig. 3.—Radiographs Illustrating Contrast on 1.5-in. Steel.

procedures. Buechner, Van de Graaff, *et al.*[17] have shown that, rather than consider the absorption coefficient as a single factor, the more significant factor upon which degradation of film images is dependent is the ratio of scattering factor to absorption coefficient K/μ. They show also that this ratio is lower for 2-mev. radiation than for lower voltages, and hence claim advantages which are now recognized for this voltage. These authors also state that the curve of K/μ displays a maximum at about 600 kv. By including the data of Seemann,[18] one can extend the curve for K/μ into the lower voltage region (see Fig. 2). It appears from this curve that an advantage greater than that obtained by going to 1 or 2 mev. can be realized by going to the lower voltages in so far as picture quality is concerned. To illustrate this point, the author recently made some X-ray film exposures to determine how great a contrast could be obtained on film for various thicknesses of steel. The low voltages provided the greatest contrast; however, the thickness which was penetrated in reasonable exposure times was small (see Fig. 3). It is indicated from these experiments that picture quality is greater at voltages much below those normally employed, but the times are excessive: that is, they are excessive when we employ film as a detecting medium. It will be interesting to see how practical these low-voltage exposures can be made for thicker sections by means of a fast detector, such as the one suggested earlier in this paper.

Thus, it can be realized that the use of the television pickup system allows an increase in picture contrast by electronic modification of the received image and a further increase in subject contrast by allowing the use of lower voltages for a given thickness. This latter advantage can probably be realized only for those thicknesses now requiring a voltage of 600 kv. or less. Because of the peak in the K/μ curve at 600 kv., thicknesses requiring greater voltages (1000 kv.) for a film radiograph probably would not show improvement at a lower voltage, unless a very great increase in speed can be realized, such as to permit a drop in voltage to well below the critical point at 600 kv.

Greater Flexibility of Picture Characteristics:

This discussion, like the discussion on improved quality, is based on the development of the high-speed television picture detector. Anyone who has been exposed to the publicity surrounding the release of television for public consumption must realize that most television receivers are equipped with panel controls labeled "contrast" and "brightness," among others. Actually, the viewer can alter these picture characteristics as his discretion and for his own satisfaction by the twist of a knob. The change in character of the picture with regard to these variables is instantaneous, and the range of adjustment large. In effect, the television circuitry covers the range of many different types of film, photographic or X-ray, and does so rapidly and easily. Such variability of contrast, coupled with a variable speed of response (sensitivity), also easily provided for electronically, represents an ideal set of characteristics for practical radiography. With such a range and speed of adjustment, the radiographic technician can come pretty close to forgetting the characteristic called latitude. If a specimen being examined presents too great a subject contrast to be viewed in any area, those portions of the picture which are outside the viewing range may be quickly brought to optimum viewing conditions. In other words, the technician should not have to consider the contrast or latitude of the whole picture area and choose his picture characteristics so as to place the entire area in a readable range. He may adjust for optimum viewing conditions over any small part of the area and rapidly vary these conditions to suit the parts of the area, one after another. This procedure would correspond to the making of numerous film exposures to produce optimum image visibility for all portions of a complex area.

Conclusions

It is concluded that the most profitable line of investigation in the field of radiographic testing involves the development of new and improved detection techniques. Suggested techniques, employing television and other electronic principles, show promise of improvement in both the quality of inspection data and the speed with which they can be obtained.

The ultimate end product of such developmental efforts can be automatic or semiautomatic inspection instrumentation, serving in modern, high-speed, industrial production. Increased assurance of the quality of production over that obtained by spot check or sampling methods may thereby be realized.

[17] W. W. Buechner, *et al.*, "An Investigation of Radiography in the Range from 0.5 to 2.5 Million Volts," ASTM Bulletin, No. 155, December, 1948, p. 54; also Papers on Radiography, p. 75, Am. Soc. Testing Mats. (1950). (Issued as a Separate publication *STP No. 96*.)

[18] H. E. Seemann, "Secondary Radiation in the Radiography of Aluminum, Steel, and Lead," *Proceedings*, Am. Soc. Testing Mats., Vol. 38, Part II, p. 284 (1938).

The Mechanical Properties of Wood

A book has recently come to our attention covering the technical aspects of wood is that entitled, "The Mechanical Properties of Wood," written by Frederick F. Wangaard, Assistant Professor of Forest Products, Yale University. Although intended primarily as a textbook for students of wood technology and wood utilization, this book contains extensive information on the technical properties of wood. The many new developments in timber mechanics and timber engineering and the increased knowledge of the effects of the various factors on the properties of wood are covered.

There are four parts which take up, respectively, the basic mechanical properties of clear wood, factors affecting mechanical properties of wood, working stresses for structural lumber, and timber testing. This last part includes descriptions of various tests among which are several recognized ASTM methods. An appendix contains a simple plan for testing small clear specimens of wood. Copies of this book may be secured from John Wiley & Sons, Inc., 440 Fourth Ave., New York 16, N. Y., at a cost of $6.

Bibliography of Electron Microscopy

A new compilation of technical literature on electron microscopy has just been issued by the National Bureau of Standards. In the past few years the field of electron microscopy has expanded so rapidly that present bibliographies are out of date; many users of electron microscopes have requested the Bureau to publish this up-to-date bibliography.

The titles of the publications have been grouped in broad categories as books, survey articles, instrumentation, electron optics, related instruments, and applications. Within each group the arrangement is chronological, and within each year it is alphabetical by author. Each reference is consecutively numbered, and a special author index refers to these numbers. Only those papers having a direct bearing on electron microscopy and published before January 1, 1950, have been included. Semiscientific, popular accounts, and patent literature have been omitted.

Circular 502, *Bibliography of Electron Microscopy*, by C. Marton, S. Sass, M. Swerdlow, A. Van Bronkhorst, and H. Meryman, 87 pages, 25 cents a copy, is available from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.